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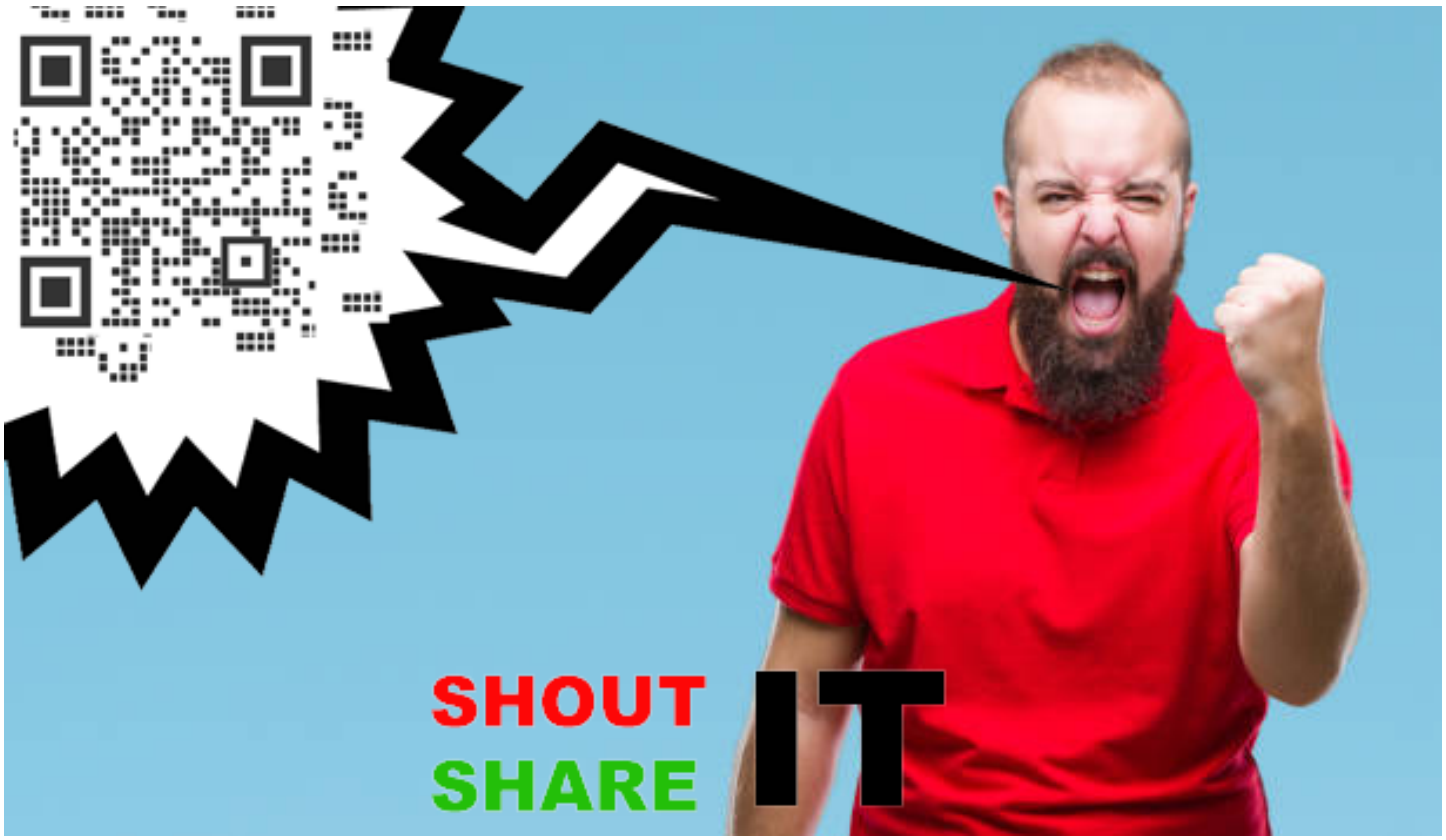
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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 428

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER January 9, 1917

MEDICAGO FALCATA, A YELLOW-FLOWERED ALFALFA.

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INTRODUCTION.

Eight years have elapsed since *Medicago falcata* L. was brought to this country with the serious view of utilizing it as a cultivated forage crop.[1] During this period much attention has been directed to-

[1] From 1910 to 1913, inclusive, investigations were conducted with *Medicago falcata* at Brookings, Highmore, and other points in South Dakota in cooperation with the South Dakota Agricultural Experiment Station.

The writers wish to acknowledge their indebtedness to Mr. H. L. Westover for valuable assistance rendered in translating botanical descriptions and in reviewing literature and to Mrs. Katherine S. Bort for assistance in connection with the literature consulted in the preparation of the subject matter.

Note.—This bulletin is intended primarily for those who are interested in alfalfa breeding.

ward the species in various ways and an interest manifested in it that is quite as widespread as that in any other plant immigrant of recent times. The fact that it is classed as a variety of alfalfa would alone have been sufficient advertisement, but to be described as a hardy and drought-resistant strain obtained for it at once almost universal recognition. Eight years would appear to be a sufficient period of time in which to determine to a reasonable degree the agricultural merits of any new crop, but in the case of *Medicago falcata* more time will be required before the true status of this species can be ascertained and its value accurately estimated.

It is true that many of the investigators who have worked with it, or rather with a few forms of it, have long since condemned it as being of little value. On the other hand, a few have seen in it the solution of the whole problem of a hardy and drought-resistant alfalfa. Both of these views are undoubtedly extreme, the first being based on scanty information or a study of insufficient material; the second, somewhat at least on sentiment. Those who have worked carefully and open-mindedly with all the available forms of the species are convinced that certain forms have much potential value if properly utilized.

One of the purposes of this bulletin is to correct many of the extreme and erroneous opinions that have obtained regarding *Medicago falcata* by setting forth in as fair and unbiased a manner as possible what are believed to be reliable data for the aid of plant breeders and others who are interested in the species.

INTRODUCTION OF MEDICAGO FALCATA INTO THE UNITED STATES.

The first importation of *Medicago falcata* to the United States of which there is a record was made by the Department of Agriculture in 1897, through the instrumentality of Prof. N. E. Hansen, who was commissioned by the Secretary of Agriculture to visit Europe and Asia for the purpose of procuring promising plants new to the agriculture of this country. Accidental importations of seed were made at an earlier date, as indicated by specimens of fully developed plants found in the United States National Herbarium, collected in Delaware by A. Commons in 1896. The collector's notes merely state that the plants were found growing in waste places. Such accidental introductions as may have occurred failed to produce any considerable number of plants in this country, since the species even now is not common in any locality.

Since 1897 the Department of Agriculture has conducted a systematic search for the numerous forms of *Medicago falcata*. This has been inspired partially by the belief that the species of itself

possesses promise as a forage crop in the colder and drier portions of the country and partially because of the recognized part which it has played in the development of the most hardy and drought-resistant commercial strains of alfalfa and the promise it presents from a plant-breeding standpoint. In connection with this systematic search, Prof. Hansen made two trips to Europe and Asia for the express purpose of collecting seed of the numerous forms of the species. The first trip was made in 1906 and the second in 1908. Mr. Frank N. Meyer, the department's regular agricultural explorer, has also devoted much attention to procuring seed of the various forms of the species, especially from localities in Asia. The efforts of both explorers were directed by the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry. Through its contacts with various collectors and investigators that office has, in addition, succeeded in obtaining a large number of forms from many parts of the Old World where the species is indigenous, so that the collection now in the possession of the department is probably more nearly complete than any that has previously been brought together. Furthermore, it probably represents nearly all of the striking forms at present in existence.

As in the case of many other wild plants, difficulty attended the procuring of seed, so that only small quantities of most of the forms were obtained. In a few cases, however, collectors offered to supply it at a comparatively low price, approximately $1 per pound.

Each lot of seed procured by the Department of Agriculture was assigned a regular accession number, which serves the purpose of identification. Below is a list of these numbers, together with brief notes taken from the published inventories of the Office of Seed and Plant Introduction.

842. 50 miles east of Rovnaya, Russia.
9748. Madrid, Spain. From Botanic Gardens.
19534. Valuiki, Samara Government, Russia.
20717. Kharkof Province, Russia. From wild plants.
20718 and 20719. Omsk, Siberia. From wild plants.
20720. Irkutsk, Siberia. From hay in market.
20721. Samara Province, Russia. From wild plants.
20722. Saratof Province, Russia. From wild plants.
20724. Tomsk, Siberia. From wild plants.
20725. Don Province, Russia. From wild plants.
20726. Samara Province, Russia. From wild plants.
23625. Orenburg, Russia.
24452. Obb, Tomsk Province, Siberia. From wild plants.
24453. Omsk, Akmolinsk Province, Siberia. From wild plants.
24454. North of Irkutsk, Siberia. From wild plants.
24455. Ten miles north of Semipalatinsk, Siberia. From wild plants.
24456. Station Charonte, Siberia. From wild plants.

26927. Kashmir, India. From plants grown under irrigation.
28041. Between Dushet and Passanura, Caucasus, Russia. From wild plants.
28070. Semipalatinsk region, Siberia. From wild plants.
28071. Orenburg region, Russia. From wild plants.
28918. Christiania, Norway. From Botanic Garden.
28940 and 28941. Copenhagen, Denmark. From Botanic Garden.
29139. Lahul, India.
29913. Jerusalem, Palestine.
30027. Svalof, Sweden. From wild plants as found in Sweden.
30200. Lower Austria. From wild plants.
30433. Leh, India.
30436. Kargil, India.
30955. Valley of the Chong Djighilan, Tien Shan Range, Chinese Turkestan. From wild plants.
31005. Petrograd, Russia. Botanic Gardens.
31303. Valley of the Chong Djighilan, Tien Shan Range, Chinese Turkestan. From wild plants.
31649. Iskardo, India.
31956. Nice, France.
32178. Ust-Kamenogorsk, Siberia. From wild plants.
32179. Along River Tom, near Tomsk, Siberia. From wild plants.
32180. Kuznetsk district, east of Barnaul, Siberia. From wild plants.
32389. From western Siberia.
32409. Near Sarepta, Russia. From wild plants.
32411. Near Saratof, Russia. From wild plants.
32412. Krassny Koot, Samara Government, Russia. From wild plants.
33465. Semipalatinsk, Siberia.
34116. Vicinity of Semipalatinsk, Siberia. From wild plants.
35311. Novospassko, Russia. From wild plants.
35312. Omsk district, Siberia. From wild plants.

The above list of introductions would indicate that the efforts of the Department of Agriculture were not confined to obtaining seed from a particular locality or region. Nevertheless, since the project was inaugurated mainly to aid in the solution of the hardy and drought-resistant alfalfa problems, special attention was focused on parts of Russia and Siberia having climatic conditions comparable with the colder and drier portions of the North and Northwest. Although many plants, especially perennials, are found growing under a wide range of climatic conditions, it is nevertheless of interest in the case of the introduction of *Medicago falcata* to compare certain features of the climate of points in Russia and Siberia, where the species is found growing naturally in some abundance, with points in the northern and northwestern parts of the United States. Table I indicates the seasonal and normal annual precipitation and the maximum, minimum, and mean annual temperatures for points in Russia and Siberia and in certain Northwestern States.

TABLE I.—*Seasonal and normal annual precipitation and maximum, minimum, and mean annual temperatures of points in Russia and Siberia and in some of the Northwestern States.*

Locality.	Precipitation (inches).					Temperature (°F.)		
	Winter.	Spring.	Summer.	Autumn.	Annual.	Maximum.	Minimum.	Normal annual.
Russia and Siberia:								
Charonte	1	1 to 2	8 to 12	2 to 3	12 to 18	97.5	−53	32
Irkutsk	1 to 2	2 to 3	6 to 8	4 to 6	13 to 19	103	−51	32
Kharkof	3 to 4	4 to 6	6 to 8	4 to 6	19 to 28	97.5	−40	42
Lake Baikal region	1	1 to 2	8 to 12	1 to 2	11 to 17	103	−58	32
Omsk	1	2 to 3	6 to 8	2 to 3	11 to 15	98.5	−56	32
Orenburg	3 to 4	3 to 4	4 to 6	3 to 4	13 to 18	105.5	−43	39
Semipalatinsk	1	1 to 2	3 to 4	2 to 3	7 to 9	106.5	−51	39
Saratof	3 to 4	3 to 4	4 to 6	4 to 6	14 to 20	108	−40	42
Tomsk	3 to 4	3 to 4	8 to 12	4 to 6	18 to 26	95	−60	32
Yakutsk	1	1 to 2	4 to 6	2 to 3	8 to 12	102	−84	14
Montana:								
Havre	1.79	3.58	6.00	2.30	13.67	108	−57	41.9
Billings	1.64	5.57	4.65	3.10	14.96	112	−49	47.2
Glasgow	1.65	4.82	4.02	2.04	12.53	113	−56	40.2
North Dakota:								
Minot	1.24	4.12	7.44	3.26	16.06	109	−47	38.8
Dickinson	1.39	4.70	7.17	2.32	15.58	110	−47	40.4
Bismarck	1.66	5.42	7.66	2.90	17.64	107	−45	40.0
Jamestown	1.88	5.66	9.29	3.19	20.02	106	−40	39.9
Devils Lake	1.52	5.24	10.07	3.33	20.16	103	−44	36.4
South Dakota:								
Pierre	1.40	5.44	7.44	2.35	16.63	110	−40	45.6
Huron	1.57	6.56	9.36	3.61	21.10	108	−43	42.1
Rapid City	1.36	6.26	8.25	2.82	18.69	106	−40	45.2
Highmore	.90	5.03	8.01	2.81	16.75	108	−45	44.7
Nebraska:								
Valentine	1.74	6.85	10.03	3.84	22.46	106	−38	46.3
North Platte	1.34	6.08	8.39	3.05	18.86	107	−35	48.2

NATURAL DISTRIBUTION.

In both Europe and Asia *Medicago falcata* has a very wide distribution, as the previous list and accompanying map would indicate. (Fig. 1.) The data from which this map was prepared were obtained from various published floras of Europe and Asia and from correspondents and explorers of the Department of Agriculture. The points where the species has been reported in literature as being found growing wild are designated, as well as those localities from which seed has been collected from plants growing without cultivation and sent to this country. To what extent the distribution of *Medicago falcata* is strictly a natural one can be estimated only broadly. However, the chances are very much in favor of the species being truly indigenous over a large portion of its present range, with the possible exception of western Europe, since its dissemination through the agency of man has been very largely incidental.

Outlining the distribution of *Medicago falcata* by means of the data that are available, it is found to occur in moist western England, in Norway to the sixtieth parallel of latitude, and generally throughout Sweden. It is common in central and southern Russia and in Austria, France, Spain, and other Mediterranean countries. In Siberia its range extends north at least to the sixty-third degree of

latitude in the mountain regions of Vilyuisk and Yakutsk. Han-

FIG. 1.—Sketch map of Europe and portions of Asia, showing (by round dots) the localities where *Medicago falcata* has been found growing wild and (by small crosses) the localities from which seed of this species has been imported by the United States Department of Agriculture.

sen (*26*, p. 10, 14)[1] is of the opinion that its northeastern limit is be-

[1] The numbers in italic type refer to "Literature cited," pp. 67–70.

tween Verkhoyansk and Yakutsk and that Lake Baikal may be considered its eastern limit with the exception of the locality around Verkhneudinsk, more than 100 miles east of Lake Baikal and Charonte. The range of the species in eastern Asia extends southward to Peking and westward following the northern edge of the great Mongolian Desert, including the region south of the Transbaikal Mountains and across the Himalayas into northern and western India. Continuing westward, it extends through Turkestan, Persia, Syria, Palestine, and European Turkey. So far as has been reported, the species is not indigenous along the Mediterranean region in northern Africa.

There are no localities in which *Medicago falcata* is especially abundant throughout the wide region over which it occurs. According to Meyer and others, the section of Siberia in which it is most abundant is that lying to the north of Semipalatinsk. Hansen reports it to be very common in the Provinces of Tomsk and Akmolinsk in western Siberia; likewise in the country adjacent to the Irtish River and in the district immediately to the east of Lake Baikal. According to Dr. N. H. Nilsson,[1] of the Experiment Station, Svalof, Sweden, it is found in considerable abundance on dry, sandy soils in many parts of Sweden.

CLIMATIC AND SOIL REQUIREMENTS.

Medicago falcata occurs naturally under a great variety of soil and climatic conditions. It is found in moist as well as in dry climates and on soils ranging in character from stiff, heavy clay to almost pure sand. That its requirements with regard to both factors are similar to those of *Medicago sativa* is clearly shown in the nature of its distribution. However, it seems to have a greater range of general adaptability than *Medicago sativa* and is also less exacting in both its soil and climatic requirements.

It is on the dry steppes of Russia and Siberia that the species attains its greatest importance, and over a large portion of that general region it is a fairly common constituent of the native vegetation. The area in which it is most plentiful under humid climatic conditions is in Norway and Sweden on sandy soils, the calcareous nature of which doubtless has much to do with its abundance.

With regard to altitude, the species has an unusual range from below sea level in Palestine to 13,000 feet elevation in Afghanistan, according to J. G. Baker (*4*). Meyer found forms of it growing at an altitude of over 4,000 feet between Dushet and Passanura, Caucasus, Russia, and at 3,700 feet in the Valley of the Chong Djighilan, Tien Shan Range, Chinese Turkestan. Booth Tucker[1] reports it as occurring in India in the Lahul Valley at an elevation of between

[1] In letter on file in the United States Department of Agriculture.

10,000 and 11,000 feet, in a region surrounded by glaciers and covered with snow during the winter months.

With regard to temperature, there are few perennial species that are found growing naturally under the extremes of heat and cold that occur throughout the natural range of *Medicago falcata*. In parts of India and southwest Asia it is subjected to extremely high summer temperatures, but is exposed to only a moderate winter climate. In the vicinity of Yakutsk, Siberia, it meets with hot, dry summers and temperatures as low as —84° F. during the winter. Between these extremes it is found growing naturally under equable climatic conditions in parts of western Europe, notably in Spain and France and in the Scandinavian Peninsula.

Growing as it does under such a great variety of conditions—in many cases remote from the influence of agriculture or commerce—it is not surprising that the species has developed many forms and that it exhibits a tendency toward the production of types peculiar to the various natural geographic regions. That such is the case is strongly indicated by the many introductions made by the Department of Agriculture from numerous localities. However, it will require careful and extensive investigations to determine to what extent in this species plant type is correlated with natural conditions. The material which the department has succeeded in obtaining shows rather clearly that the forms from the high steppe regions of Russia and Siberia are in general quite different from those commonly found in northern India and from at least some of the forms found in southern Russia.

From the vicinity of Irkutsk, Siberia, the department has obtained a distinct form, apparently peculiar to that region, which is characterized by its broad crown and very fine decumbent stems. This region, it will be noted, has a normal annual precipitation of 13 to 19 inches, fairly well distributed throughout the year. The extremely broad-crowned decumbent forms have been procured only from southern Russia in the general region represented by the Provinces of the Don Cossacks and Kharkof. The forms commonly found in India approach sweet clover (*Melilotus alba*) in general appearance, especially in color and texture of foliage, and are quite distinct from those of the high steppes of Russia and Siberia. So far as the material in the possession of the department indicates, the closest resemblance to the forms from India is found in certain forms procured from southern Austria and said to be native to that region.

BOTANICAL HISTORY.

The accounts of *Medicago falcata* appearing in old literature are chiefly botanical, and in most cases very brief. However, they are sufficiently clear to indicate that the species was well known, at least

to collectors, early in the history of modern botany. The reference cited by Kaspar Bauhin (*8*) and by subsequent botanists as the earliest mention of the species is made by Bock (*10*), who designates his plant as *Melilotus majoris species tertia* and describes it in such a way as to leave a reasonable doubt as to whether it is really *Medicago falcata* or some other species, possibly *Medicago arborea* L. In 1561 Gesner (*24*) published a brief description of it under the name *Trifolii genus medica similis*, mentioning the fact that it has yellow flowers and only slightly coiled pods. This reference may, with a reasonable degree of certainty, be regarded as the first positive mention of *Medicago falcata* in literature, since the identity of Bock's plant is somewhat in doubt. It is true that Kaspar Bauhin (*8*) cited *Trifolii genus medica similis* as a synonym of both *Medicago falcata* and *Medicago lupulina* L., but Gesner's description precludes the possibility of his having the latter species in mind.

By far the best of the early descriptions of *Medicago falcata* is furnished by Clusius (*33*), appearing in 1583. The name *Medica luteo flore*, which he applied, is, in a true sense, a descriptive one, and the description accompanying it treats in considerable detail of the diagnostic characters of the species. Furthermore, a good illustration of the plant, apparently the first one ever published, appears with the description (fig. 2).

Tabernæmontanus (*58*) describes and figures *Medicago falcata* as *Lens major repens*. The description is not convincing, but the figure leaves no doubt as to the identity of the plant. The generic name "Lens" was applied by Tabernæmontanus to various species of Leguminosæ without regard to their relationship.

The name finally chosen by Kaspar Bauhin for the species was *Trifolium sylvestre luteum siliqua cornuta* or *Medica frutescens*. This designation was published in 1623 (*8*).

It was about the time of Johann and Kaspar Bauhin, when the species became the subject of more general study and discussion, that mention of forms that are now known to have been hybrids began to appear in such a manner as to confuse the nomenclature somewhat. It is evident from their writings on *Medicago falcata* that both of the Bauhins fell into errors through their failure to recognize the hybrid nature of the plants which they described.

The name *falcata* was first used in connection with *Medicago falcata* by Rivinus in 1690 (*50*). He used it in a generic sense, dividing what was formerly known as Medica into two groups (Falcata and Cochleata), the distinguishing characters being the degree of twist or coil of the pod. *Medicago falcata* fell in the first division and was designated simply as Falcata. Together with the name, Rivinus published an excellent illustration, which is the first unmistakable figure of a *Medicago sativa* × *falcata* hybrid. Rivinus's

name *falcata* in reality applied to the hybrid forms most closely resembling *Medicago falcata*.

In 1694 Tournefort (*59*), following in a general way the classification of Rivinus for the Medica group, took up the old generic name Medica for the plants with screw-shaped pods and coined a new one, Medicago, for those having pods shaped like a collar. Both *Medicago sativa* and *Medicago falcata* were included by him under Medica, the former as *Medica major erectior floribus purpurascentibus* and the latter as *Medica sylvestre*. It is apparent that he intended *Medicago radiata* L. to illustrate the type of his genus Medicago. From his classification it is quite evident that the distinguishing character which Tournefort had uppermost in his mind was the shape of the pod. He was not consistent, therefore, in placing *Medicago falcata* in the genus Medica, since the true form of it does not have the spiral or screw-shaped pod which characterizes his genus. Possibly his knowledge of *Medicago falcata* was confined to the hybrid forms having loosely coiled pods, in which case his arrangement is partially justified.

FIG. 2.—Probably the first figure of *Medicago falcata* ever published. Copied from Clusius, Historia, 1583 edition, where it first appeared.

In 1700 Tournefort (*60*) simplified the description of his genera somewhat and added varieties of his *Medica major erectior* (*Medi-*

cago sativa) and also varieties of *Medica sylvestris* (*Medicago falcata*). His varietal classification is based on the color of the flowers, and was doubtless developed from Kaspar Bauhin's description (*8*). It is essentially the same for both species. Tournefort must be given credit for the first attempt at a classification of the varieties of *Medicago falcata*, whatever its value may be, and also for the first botanical usage of the word which was finally to become its generic name.

It was Vaillant (*63*) who placed *Medicago falcata* in the genus Medicago of Tournefort, but it remained for Linnæus to enlarge and define the genus and to assign the name *Medicago falcata* to the species. This he did in 1753 (*40*). A copy of Linnæus's original description of *Medicago falcata* follows; likewise an elaborated outline of the references derived from those accompanying it.

Original description of Medicago falcata.

falcata. 6. Medicago pedunculis racemosis, leguminibus lunatis, caule prostrato. Fl. suec. 620. Dalib. paris. 229.

Trifolium sylvestre luteum, siliqua cornuta. Bauh. pin. 330.

Medica flavo flore. Clus. hist. 2, p. 243. *Habitat in* Europæ *pratis apricis*, siccis. 4.

ELABORATED OUTLINE OF CITATIONS.

[The numbers in italic type refer to "Literature cited," pp. 67–70.]

LINN Sp. Pl. (*40*).

- Fl. suec. 620 *b* (*39*)..
  - Hort. Cliff. p. 377 *b* (*38*)..
    - Riv. tetr.*a* (*50*).
    - Dill. giss. 148 (*19*).....
      - Riv. Irr. T.*a* (*50*).
      - J. B. 2. 383 *b* (*6*).
      - C. B. 330 *b* (*8*).
    - Dill. gen. 130 (*20*).....
      - D. Rivinus.*a* (*50*).
      - Tournefort *b* (*60*).
    - Bauh. hist. 2. p. 383 *b* (*6*).
    - Tournef. inst. 410 *b* (*60*).
    - Clus. hist. 2. p. 243 *a* (*34*).
    - Moris. hist. 2. p. 157 s. 2. t. 16 f. l. & s. 2. t. 15 f. l. (*44*).
      - J. B. Chabr.*b* (*15*).
      - Clus. Hist.*a* (*34*).
    - Bauh. pin. p. 330 *b* (*8*).
  - Bauh. hist. 2. p. 383 *b* (*6*).
    - Taber.*a* (*58*).
    - C. Bauh. phyt. (7).....
      - Trago pag. 591, libr. 2. cap. 3, sineicone *a* (*10*).
      - Clus. histor. Pann. pag. 759, libr. 4, cap. 33*a* (*33*).
  - Tournef. inst. 410 *b* (*60*)..
    - J. B. 2. 383 *b* (*6*).
    - C. B. Pin. 330 *b* (*8*).
    - Clus. hist. CCXLIII *a* (*34*).
  - Clus. hist. 2. p. 243 *a* (*34*).
  - Bauh. pin. 330 *b* (*8*).
- Dalib. paris. 229 (*17*).
  - fl. suec. 620 *b* (*39*).
  - hort. cliff. 377 *b* (*38*).
  - fl. leyd. prodr. 381 (*52*)..
    - Linn. h. Cliff. 377 *b* (*38*).
    - Riv. tetrap. 84 *a* (*50*).
    - Dill. giss. 148 *b* (*19*).
    - Dill. gen. 130 *b* (*20*).
  - bot. par. (*63*).....
    - J. B. 2. 383 *b* (*6*).
    - Tournefort (indirectly).
  - Bauh. hist. 2. 383 *b* (*6*).
  - Tournefort—?
- Bauh. pin. 330 *b* (*8*)..
  - Trag.*a* (*10*).
  - Ges.*a* (*24*).
  - Clus. pan. & hist.*a* (*33*).
  - Tab.*a* (*58*).
- Clus. hist. 2. p. 243.*a* (*34*).

a No further citations. *b* Elaborated as indicated elsewhere in this outline.

Beginning with the four citations given by Linnæus, the outline indicates the exact manner in which citations are made by various authors, using the abbreviations just as they are found. In many cases the same work is referred to in different ways, which is confusing unless care is exercised in interpreting the abbreviations. A few words of explanation regarding the outline may make it more easily understood.

Linnæus's first citation, it will be noted, is "Fl. suec. 620." In this work are found five citations, the first being "Hort. Cliff. p. 377," which in turn cites eight works, four of which were previously cited in "Fl. suec.," and the first one of which, "Riv. tetr.," makes no further citation, as indicated by the footnote. The others that are not previously cited are further elaborated until works are reached in which no further citations are made. Those that are previously cited are elaborated where they first appear, as, for instance, "Bauh. hist. 2. p. 383," where it appears as a citation of the "Fl. suec." instead of as a citation of "Dill. giss." The outline indicates all the references to *Medicago falcata* that can be traced from Linnæus (*40*) as a starting point.

An examination of the botanical descriptions contained in the works listed in the outline shows very clearly that, while many of the citations refer to true forms of *Medicago falcata*, others refer to hybrid plants and a few confuse *Medicago falcata* and *Medicago sativa*. Following is a classification of the citations, with regard to the plants to which they refer.

Citations that refer to apparently true forms of Medicago falcata.

Linnæus (*39*),[1] Clusius (*33, 34*), Gesner (*24*), Tabernæmontanus (*58*), Kaspar Bauhin (*7*), Johann Bauhin (*6*), Dillenius (*20*).

Citations that refer to what are apparently hybrids between Medicago sativa and M. falcata.

Kaspar Bauhin (*8*), Tournefort (*60*), Rivinus (*50*), Morison (*44*), Chabré (*15*).

Citations that contain only descriptions copied from other authors.

Dalibard (*17*), Royen (*52*), Vaillant (*63*), Dillenius (*19*).

Citation in which Medicago falcata and M. sativa are apparently confused.

Linnæus (*38*).

[1] The numbers in italic type refer to "Literature cited," pp. 67–70.

BOTANICAL DESCRIPTION AND RELATIONSHIP.

BOTANICAL DESCRIPTION.

The description of *Medicago falcata* given by Linnæus in 1753 (*40*), when the binomial was first published, merely indicates that the peduncles are racemosely arranged, that the pods are crescent shaped, and that the stems are prostrate in habit of growth. This, as a matter of fact, can scarcely be considered as a description, since it is in reality only a part of an analytical key to certain species of the genus Medicago. Various descriptions, however, have appeared since that of Linnæus. A fairly good one was published by Lamarck in 1789 (*31*) and another by Martyn in 1792 (*43*).

The difficulty of preparing a satisfactory description becomes at once apparent upon consideration of the numerous forms of the species. Many of the early ones are confusing because their authors failed to recognize the existence of hybrids among the forms which they attempted to describe, and all of them are imperfect, since in no place was a complete collection of the forms of the species available. Even at this time, with the work of others from which to draw and with the abundant material at hand, it is far from easy to prepare a description that will present a comprehensive view of the species. The diversity of *Medicago falcata* inspires the investigator at once with the desire to attempt a classification that will fit all existing forms. However, it requires only a little investigation to convince one of the hopelessness of such a task.

In the main there are two difficulties in the way of developing a satisfactory scheme of classification—the lack of consistency in the combinations of characters and the practical impossibility of determining from one generation of plants whether a form is of pure or hybrid origin. There is, however, a certain correlation of characters which permits a general grouping, although intergrading forms are so common that it frequently is difficult to differentiate the mass even into broad groups.

To serve as a basis for further discussion of botanical characters it seems advisable, first, to present some rather detailed data, including observations and careful measurements made in connection with the study of a large number of plants secured from many sources, these constituting a composite description of the species. Following these data an attempt is made to correlate certain characters and to define the principal groups and describe them in the abstract. It is hoped that this method of treatment, together with illustrations reproduced from photographs, will convey a reasonably clear idea of the appearance of the striking forms of *Medicago falcata*.

COMPOSITE DETAILED DESCRIPTION.

The flowers of the numerous forms of the species vary considerably in color, size, and shape of banner, length of calyx teeth, and slightly in length of calyx tubes. There is also a variation in the length of pedicels, the number and compactness of the racemes, the number of flowers in the raceme, and the date of blooming. In color the flowers range from a light yellow to a deep chrome yellow, the pale yellow color being the most prevalent in the individuals that more nearly approach *Medicago sativa* in general appearance.

On the steppes of northern Russia and Siberia occur forms that have variegated flowers. These forms are found apparently remote from forms of *Medicago sativa* and so closely associated with forms of *Medicago falcata* having pure yellow flowers that Prof. Dilitwinoff,[1] of the Academy of Sciences, Petrograd, is of the opinion that they are true forms of the latter. Meyer, however, who has studied them in their native habitat, believes them to be hybrids of *Medicago sativa* and *Medicago falcata*, and a study of the progeny of these plants grown from the seed collected by the department's explorers indicates quite definitely that Meyer's opinion is well founded. The progeny exhibits a diversity of forms, some of which closely resemble *Medicago sativa*, while others present the appearance of true *Medicago falcata*. But regardless of this, the wild variegated forms are regarded with interest in connection with the study of the origin of the cultivated alfalfas and the botanical relationship existing between the above species.

Flowers.—The individual flowers of *Medicago falcata* are smaller than those of *Medicago sativa*. The lines which mark the banners are shorter in the former than in the latter and are light to dark brown, varying directly with the color of the flower. A large number of careful measurements show that the banners vary from 6.25 to 12 mm. in length and from 2.20 to 8 mm. in width. The ratio of length to width of the banner also varies, ranging from approximately 1.2 to 1 to 3 to 1. The calyx averages about 1.75 mm. in length and varies from approximately 1.3 to 2.6 mm. There is a greater variation, however, in the length of the calyx teeth, the range being from 1.25 to 3.75 mm. The pedicels are from 1.25 to 3.75 mm. in length.

There appears to be little uniformity in the number of flowers in the raceme. In some cases as few as five are found, while in others as many as 36 may be present. Racemes with the largest number of flowers have been noted to be compact and of medium size. The very fine leaved plants and the plants with long procumbent stems have small racemes, with comparatively few flowers. Likewise, the

[1] In letter on file in the United States Department of Agriculture.

very large ascending plants with long, erect stems, as well as the broad-crowned forms, have few flowers to the raceme. The upright bushy plants with stiff stems and narrow greenish gray leaves have, in general, the largest racemes. A great abundance of flowers does not appear to be characteristic of any special form of the species. The compactness of the raceme is dependent to a large extent on the length of the pedicel, the size of flower, and the arrangement on the axis. Compact racemes are usually small, and the flowers are arranged at more regular intervals than they are in the loose racemes.

The flowers of *Medicago falcata* usually come into bloom earlier than those of *Medicago sativa*. However, the broad-crowned procumbent to decumbent plants of the former are especially late in blooming. The flowering period is much longer than in the case of *Medicago sativa*, frequently extending from May to October in South Dakota.

Pods.—The pods vary greatly in proportion of width to length and range in shape from almost straight to semicircular or more

FIG. 3.—The common types of pods of *Medicago falcata*.

nearly coiled, even in what appear to be pure strains of the species. The average pod is crescent or sickle shaped, reticulate veined, without glandular hairs, but in some cases slightly pubescent. When mature they are light brown to almost black in color. (Fig. 3.)

On pod characters it is possible to distinguish two fairly distinct types of plants. Type 1.—Pods short, broad in comparison to length, of medium thickness, nearly straight, and pointed. Pods of this type are light brown to dark brown in color, dehisce readily upon approaching maturity, and on the average contain one less seed than the average for the species. They are confined almost exclusively to the more nearly erect stiff-stemmed types of plants and are found abundantly in S. P. I. Nos. 20721 and 20722. They are well illustrated by pods Nos. 8, 9, and 10 in the top row of figure 3. It was to plants having pods of this general form that the varietal name stenocarpa (Reich.) (*49*) was apparently intended to apply. Type 2.—Pods long, narrow in proportion to length, sickle shaped to nearly coiled, brown to almost black in color. The general type is illustrated by

pods Nos. 7, 8, 9, and 10 in the second row of figure 3. This is a distinct type of pod and is found most abundantly in plants having medium broad crowns and long and decumbent to ascending stems, as shown in figure 13. They are found in S. P. I. Nos. 20726, 26927, and 30433. The number of seeds per pod averages approximately one more than the average for the species. The seeds are well retained, and the pods are quite plentifully produced. Plants bearing pods of this type set seed more liberally than other forms of the species. It must be understood that the two types of pods above described represent the extremes and that there are many intermediate forms.

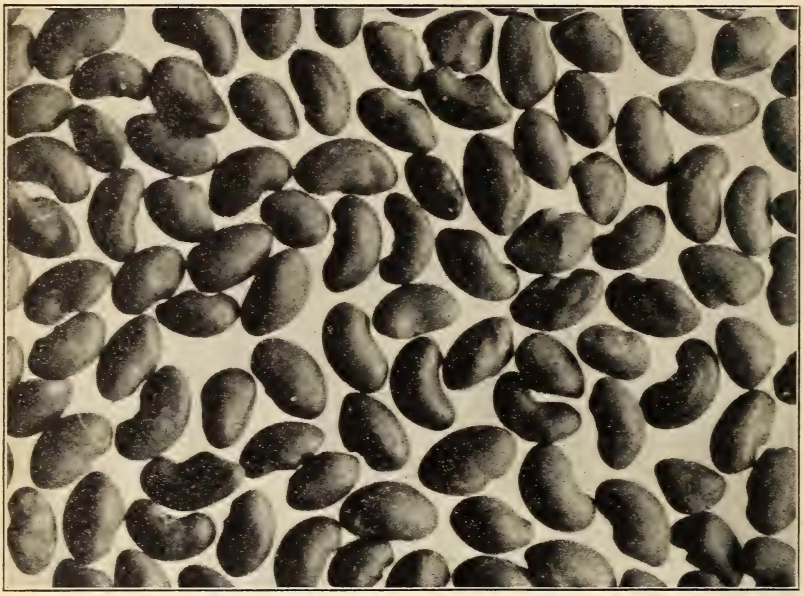
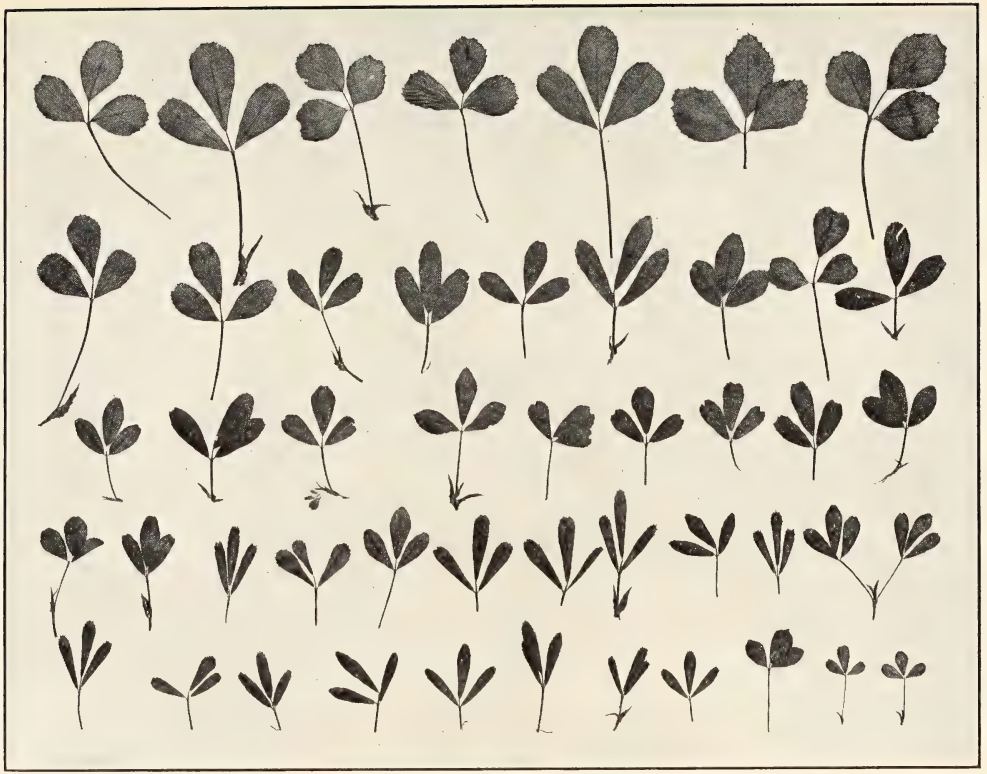


FIG. 4.—Seed of *Medicago sativa*. (Enlarged.)

Seeds.—In general appearance the seeds closely resemble those of *Medicago sativa* (fig. 4), but a careful examination shows them to be appreciably smaller and decidedly more angular. The radicle is also more prominent and in some seeds the hilum is very marked, while in others it is scarcely apparent. (Fig. 5.) When examined under a lens the seeds show a slightly roughened surface. The pitted surface together with the angular shape produces a feeling of grittiness when seeds are rubbed between the thumb and fingers. This is especially true of seeds from certain forms of plants.

The explosive mechanism of the flower is essentially the same as that of *Medicago sativa*, with the exception that more force is required to accomplish tripping and usually less energy is expended by the column upon becoming released. This condition, together



LEAVES OF MEDICAGO FALCATA.

The numerous forms of the species present great variations in the size and shape of their leaves.

STEMS OF MEDICAGO FALCATA—I.

STEMS OF MEDICAGO FALCATA—II.

STEMS OF MEDICAGO FALCATA—III.

with the scanty production of pollen in the case of many of the flowers, may be responsible to some extent for the paucity with which the seed of the species is produced.

Leaves.—The leaves vary in shape from ovate to linear-cuneate. (Pl. I.) The type and stage of growth of the plant and the position in which the leaves are borne on the stem all influence their size and shape. During the first few weeks of growth in the spring they are larger and more ovate than they are later in the season. They also appear to diminish in size and become more elongated as the end of the stem is approached. In general, they are more elongated or linear than those of *Medicago sativa*, although there are some

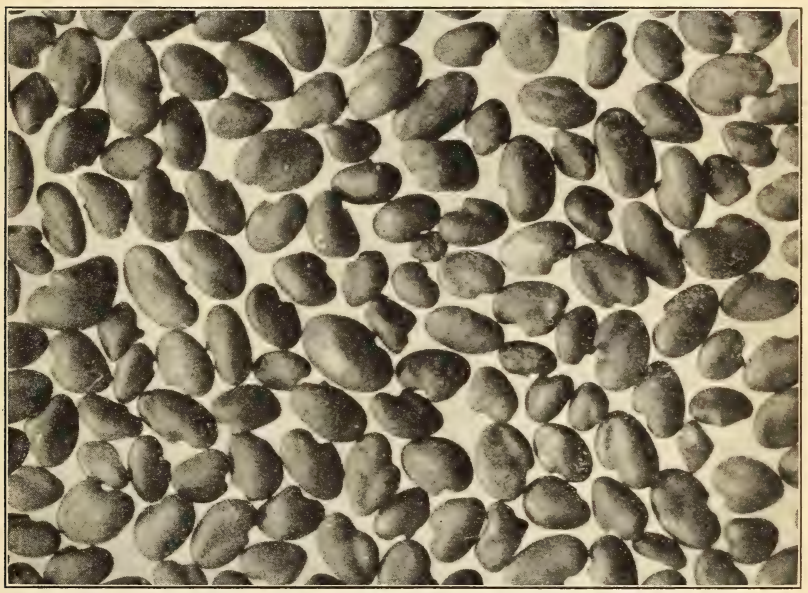


FIG. 5.—Seed of *Medicago falcata*. Note the prominence of the radicle and the roughness and irregularity as compared to those of *Medicago sativa* (fig. 4). (Enlarged.)

marked exceptions, as will be noted in the illustration. A series of measurements indicates the range of proportion of length to width to be from 1.8 to 1 to 16 to 1. The more ovate leaves are common in groups of plants represented by S. P. I. Nos. 24454 and 20725 (Pls. II, *C* and *D*, and III, *A* and *C*), while the more linear leaves are abundant in the group represented by S. P. I. Nos. 20718 and 24455 (Pls. II, *A* and *B*, and IV, *B* and *C*). The large leaflets are approximately 27 mm. long by 12 mm. wide, and the smaller ones approximately 9 mm. long by 1.5 mm. wide. The plants having the larger leaflets approach *Medicago sativa* in general characteristics. The margins of the leaves are more or less serrate; the apex deeply notched, mucronate, or in some cases nearly entire. In some leaves

the midrib forms a ridge, while in others it is decidedly depressed, being almost buried in the fleshy tissue. Prominent midribs are usually of a brownish color and occur in elongated and frequently quite pubescent leaves. The veins of the leaves are more nearly parallel than they are in *Medicago sativa* and are more symmetrical in the linear than in the obovate type. The color of the leaves varies from a greenish yellow to a dark bluish green, the quantity of pubescence affecting the color to a considerable extent. An abundance of pubescence which produces a greenish gray effect is especially noticeable on plants that have deeply notched leaves, such as are found in S. P. I. Nos. 20721 and 20722. Upon drying, the leaves of certain forms develop an almost indigo-blue color.

The abundance of leaves appears to be correlated somewhat with shape, sparseness of production being found in plants where the narrow type of leaf is predominant. Supernumerary leaflets are much more common than in *Medicago sativa*, the number of leaflets frequently reaching five in certain forms, while, on the other hand, two leafflets are very common in some forms.

The petioles are far from uniform in length and the stipules vary in shape from broadly triangular to linear, their margins varying from deeply serrate to almost entire.

Stems.—To only a limited extent are the stem characters correlated with plant type. There are some cases, however, where a correlation exists with a fair degree of consistency. In the broad-crowned forms, as found in S. P. I. Nos. 20717 and 20725, the plants have uniformly slender stems of greatly varying length. In the ascending forms, as found in S. P. I. Nos. 20721 and 20722, the stems are stiff and of medium size, while in certain decumbent plants fairly stiff trailing stems are found, some reaching 4 feet in length. These are common in plants of S. P. I. Nos. 24452 and 24454. Long, slender stems are abundant in broad-crowned, procumbent forms, as found in S. P. I. No. 24454. The plants of the bushy habit commonly have short stems. The procumbent to decumbent plants have twisted, irregular stems, while the stems of bushy plants are usually more regular and more nearly straight.

The number of stems is greatest in the broad-crowned plants and ranges in some cases from approximately 1,600 per plant in plants of this character to 300 or less in the narrow-crowned ascending forms. These data are based on plants 4 years old. Some of the stems are quite pubescent, while others are smooth. They vary from numerous shades of green to reddish brown, the color being more of a fixed characteristic than the result of seasonal conditions. A very good idea of the variation in the stems of *Medicago falcata* and also some conception of its racemes and leaves can be gained from an examination of Plates II, III (*B*, *C*, and *D*), and IV.

Roots.—Medicago falcata differs to a considerable degree from *Medicago sativa* in having a much more branching root system. In comparatively few cases is a single taproot developed, while the entire absence of the taproot proper is very common. In the majority of plants, however, there is a tendency toward the development of a much-branched taproot and a large number of small lateral roots. Meyer reports taproots of remarkable size on wild plants growing on the sandy banks of the Tom River, near Tomsk, Siberia. Some of these large roots were more than 2 inches in diameter at the crown and more than 1 inch in diameter at a depth of 14 feet; a few of them extended to a depth of more than 33 feet. Such a taproot development, however, is very uncommon in the species and occurs only in sandy or loose soils. A peculiar root system characterized by a branched taproot from which horizontal lateral roots are produced is found in some forms. The lateral roots give rise to aerial shoots, which develop ultimately into perfect and in some cases independent plants. (Fig. 6.) This type of proliferation has been previously described by the writers (*45*). It does not appear to be correlated with general habit of growth or with any important plant characters, although, as far as has been observed, it is not found in plants of the very low spreading habit. It is common in S. P. I. Nos. 24455, 28070, 28071, and 23625. The first two of these numbers were introduced

FIG. 6.—*Medicago falcata,* S. P. I. No. 28071, a 3-year-old plant grown at Highmore, S. Dak. Note the new plants that have developed from true lateral roots.

from Semipalatinsk, Siberia, and the last two from Orenburg, Russia. Root systems of similar character are found in *Rhus glabra* L., *Ambrosia psilostachya* DC., *Cirsium undulatum* (Nutt.) Spreng., *Convolvulus arvensis* L., *Ipomoea leptophylla* Torr., and numerous other species. The development of proliferating roots in certain forms of *Medicago falcata* presents a rather interesting situation from a taxonomic standpoint. So far as the writers are aware, there are no other species having two forms, one in which this character is present and the other in which it is absent.

The tendency to produce rooting rhizomes permits the development of a much more extensive root system than is ordinarily found in *Medicago sativa*. It is characteristic of many of the roots of *Medicago falcata* that they possess the ability to produce new plants if cut off at the surface of the ground or if they become exposed accidentally.

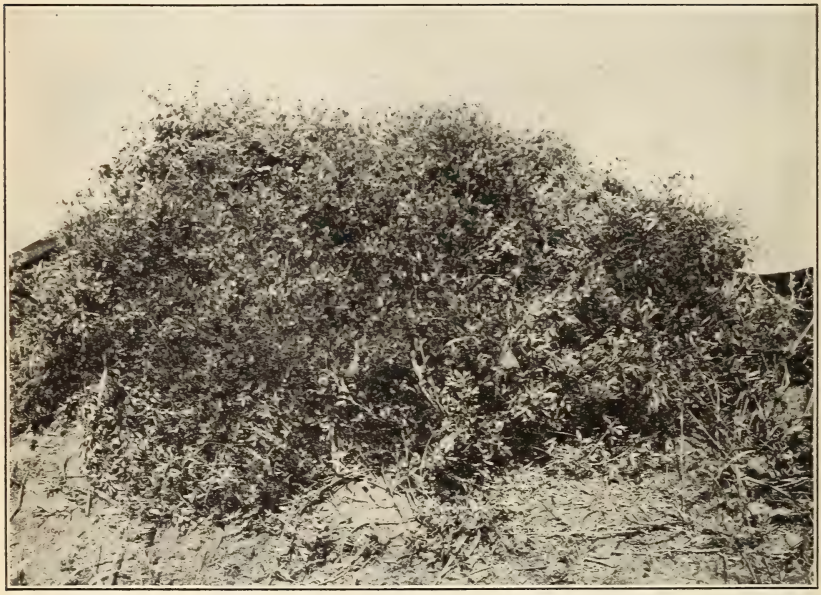


FIG. 7.—Individual plant of *Medicago falcata*, S. P. I. No. 20717, typical of the forms included in Group I.

GROUPS.

A division of the forms of *Medicago falcata* into groups may be made on the basis of several characters; for example, color, size, and abundance of flowers, type of pod and seed habits, foliage characteristics, stem types, and even root systems to a certain extent. From a strictly botanical standpoint a classification on one or more of these sets of characters would appear to be desirable, but the combinations of characters in the plants are such that a logical grouping along

these lines can not be made. In order to include in the same class the forms that most naturally resemble each other, it seems necessary to make the divisions along the line of plant type with regard to erectness, type of crown, and general habit of growth. A classification even on this basis has in it many inconsistencies, not only with regard to special botanical characters, but also in the general characteristics upon which it is founded. Its weaknesses from a botanical standpoint are fully appreciated, yet it seems to be less artificial than the other classifications that suggest themselves. It possesses the additional advantage of being based on characters of agronomic im-

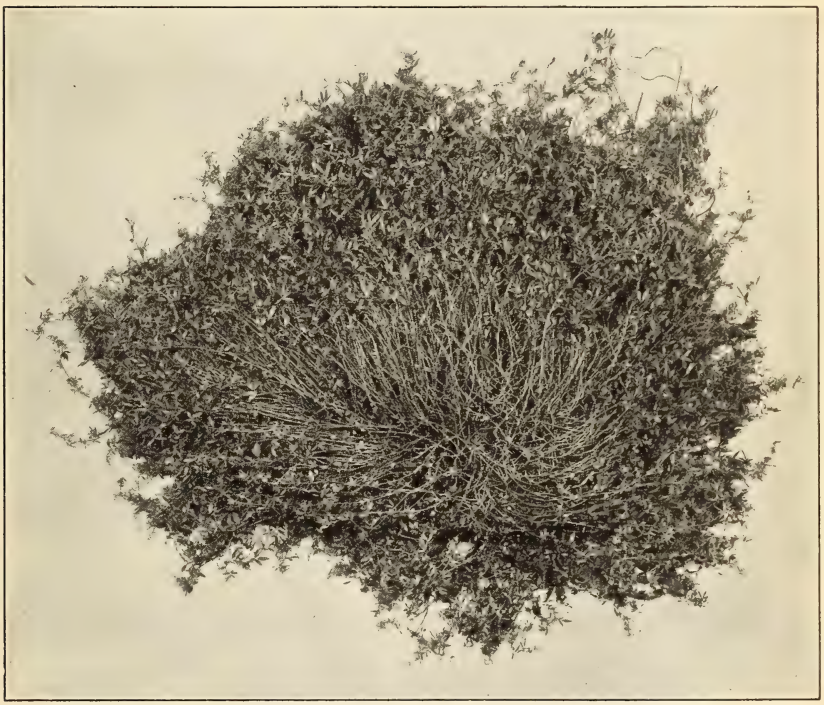


FIG. 8.—Individual plant of *Medicago falcata*, S. P. I. No. 20725, as viewed from directly above; a very procumbent, fine-stemmed form, illustrating Group I.

portance; in fact, it is perhaps more agronomic than botanical, and is certainly more in the nature of a convenient grouping than an outline of actual relationships. It is hoped that a further study of the material will result in the development of a more satisfactory classification.

The system which is adopted herein provides for four groups. Certain of these are pretty clearly defined, while some differ from others only in degree. Each group is illustrated by a figure of an individual plant, and for the benefit of those to whom the department's introductions of *Medicago falcata* are available S. P. I. numbers are cited, which include forms that are typical of the groups.

It will be noted that in certain cases numbers are referred to under more than one group. This is explained by the fact that many of the introductions as they were received from abroad contained several forms of the species. The descriptions given under each group are brief, but they are as full as the nature of the material warrants. The types or groups are as follows:

GROUP 1.—*Prostrate.*—Plants of this group are characterized by broad to very broad crowns, which have a tendency toward the development of barren centers after two or three years. (In many cases 4-year-old plants have crowns 36 inches in diameter.) The plants are of prostrate or procumbent habit of growth and are decidedly spreading. The leaves are about average in size and shape, but in the more narrow crowned plants are inclined to be of a darker color than the average for the species. The flowers are of a deep yellow color and inclined to be small, late blooming, and some-

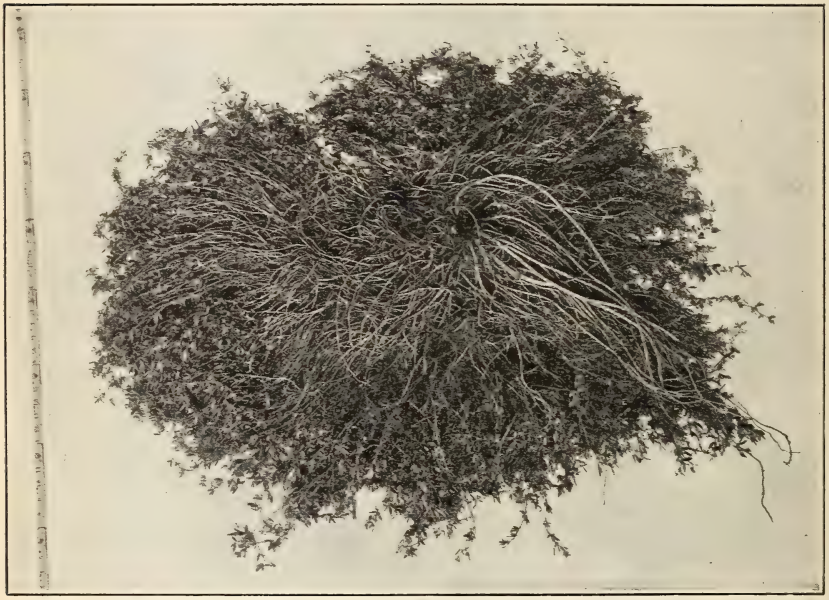


FIG. 9.—Individual plant of *Medicago falcata,* S. P. I. No. 20725, as viewed from beneath. The small whitish stems are rhizomes.

what scantily produced. The seed is produced scantily or only fairly abundantly. In the extremely broad crowned plants the stems are numerous (as many as 1,600 per plant in plants 4 years old), and individual plants having fine, short stems are common. In the more narrow crowned plants, the stems are inclined to be long and fine and less numerous than in the very broad crowned forms (approximately 300 in plants 4 years old). Plants representing this group are common in S. P. I. Nos. 20717, 20725, and 24454 and are well illustrated in figures 7, 8, and 9.

GROUP 2.—*Decumbent.*—Plants of this group have medium broad crowns, which frequently become barren at the center at the end of a few years. (Crowns of 14 inches in diameter are common in 4-year-old plants.) Habit of growth, decumbent to procumbent; flower, pod, and seed characters vari-

able; the racemes are inclined to be compact; stems of medium length, inclined to be long; leaves not especially abundant. This type of plant is common in S. P. I. No. 24452 and is illustrated in figures 10 and 11.

GROUP 3.—*Ascending.*—Plants of this group have medium broad crowns, with an average diameter less than those in group 2. Habit of growth, ascending. No striking characteristics are found generally in their flower or seed habits. Stems rather coarse, inclined to be crooked, and not especially abundant; leaves usually not abundant. This type is found quite commonly in S. P. I. Nos. 20718, 20719, 24455, 28070, and 28071 and is well illustrated in figures 12, 13, and 14.

FIG. 10.—Individual plant of *Medicago falcata,* S. P. I. No. 24452, a broad-crowned plant with long procumbent to decumbent stems, representing Group II.

GROUP 4.—*Suberect.*—Plants of this group have medium to small crowns and are ascending to erect in habit of growth. They are not characterized by special flower types, but in general produce seed sparingly. The stems are stiff and the leaves approach those of *Medicago sativa* in shape, but are smaller and more abundantly produced. This type of plant is found in S. P. I. Nos. 20718, 20719, 24455, 28070, and 28071, but not abundantly. It is well illustrated in figures 15 and 16.

There are many forms that do not fit perfectly into the above groups but fall in the zones between the groups, since they have combinations of characters that are not consistent with this classification. However, the four groups described, if interpreted liberally, can be made to cover a large majority of the forms of the species so

far obtained. From an agronomic standpoint, groups 1 and 2 represent plants which in their pure state may be considered of value only for pasturage on account of their procumbent tendencies, while groups 3 and 4 are sufficiently erect to be utilized for the production of hay. For convenience these groups may be referred to as pasture and hay groups, respectively.

BOTANICAL RELATIONSHIP.

Considerable difference of opinion exists among botanists as to the exact relationship which *Medicago falcata* bears to the group of Medicagos commonly referred to as alfalfas. By many it is given a specific rank coordinate with *Medicago sativa*. By others it is

FIG. 11.—Individual plant of *Medicago falcata*, S. P. I. No. 20726, a medium broad crowned plant, decumbent to ascending in habit of growth, representing Group II.

regarded as a subspecies of *Medicago sativa*, while some are of the opinion that *Medicago falcata* is the true species and that *Medicago sativa* is only a subspecies or a cultivated variety of it. Linnæus (*38*, *39*) at one time suggested the latter arrangement.

Urban (*62*) divides *Medicago sativa* into two sections, "*Macrocarpa*" and "*Microcarpa*," and places *Medicago falcata* under the former, coordinate with *vulgaris*, which he indicates is the common cultivated variety of *Medicago sativa*.

Alefeld (*1*) designates common alfalfa as *Medicago sativa vulgaris* and *Medicago falcata* as *Medicago sativa falcata*.

Ascherson and Graebner (*3*) follow essentially the classification of Urban, but Rouy and Foucaud (*51*), Seringe (*57*), and many

other botanists class *Medicago falcata* as a distinct species coordinate with *Medicago sativa.*

While opinions differ as to the relationship of *Medicago sativa* to *Medicago falcata*, the natural relationship is clearly indicated by the frequency and fertility of the hybrids between the two. With the exception of the forms of Medicago which Urban (*62*) assigns to *Medicago sativa* and *Medicago prostrata* Jacq. (*28*) there are no others so far reported that hybridize naturally with *Medicago sativa*—and but few that can be crossed artificially.[1]

These facts are especially significant in the Leguminosæ, where hybrids of any kind are extremely rare. A careful study of the behavior of the hybrids of *Medicago sativa* and *Medicago falcata*

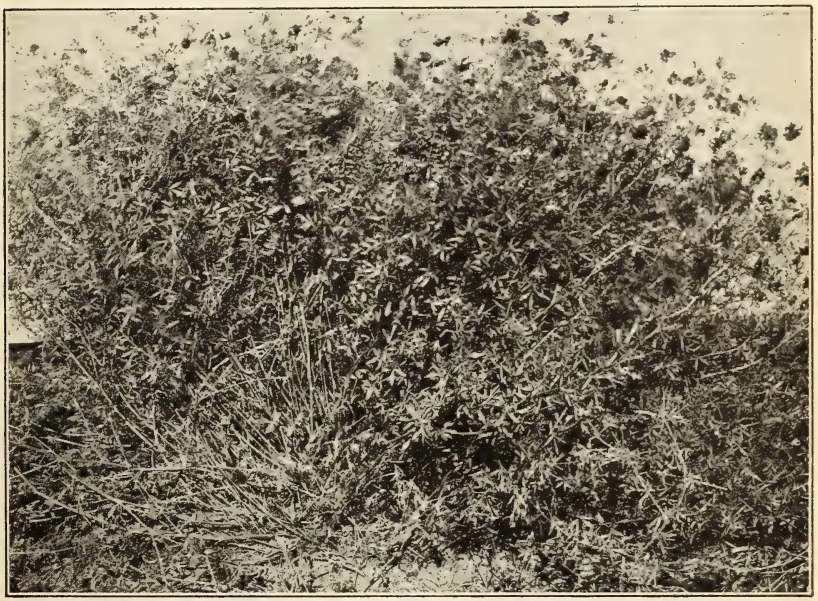


FIG. 12.—Individual plant of *Medicago falcata,* S. P. I. No. 28070, a medium broad crowned plant of ascending habit of growth, representing Group III.

points to a common origin of the parents at no very remote date in their evolutionary history. Regardless of the somewhat contradictory opinions that exist, *Medicago falcata* will be referred to throughout this paper as a true species.

Botanical names have been assigned to what appear to be true forms of *Medicago falcata* and both specific and varietal names to forms that are apparently hybrids of *Medicago falcata* and *Medi-*

[1] Hybrids of *Medicago sativa* and *Medicago prostrata* have been reported by Ascherson and Graebner, but there is a much closer relationship between these species than Urban's classification would indicate. Numerous broad crosses of legumes have been reported, including one of *Medicago sativa* and an annual or biennial species of the same genus, but they are all of doubtful authenticity.

cago sativa. In the latter instance the names were applied in many cases without knowledge of the hybrid nature of the plants. There is very little justification for the attempts that have been made to describe and name forms of true *Medicago falcata*, since the characteristics of these forms to which names have been applied are neither definite nor consistently correlated with other important characters. There would appear to be no justification for the attempts to name and describe unstable hybrids. Tournefort (*60*) was the first to do this, but he was not aware that the forms with which he dealt were hybrids. More recent botanists likewise have apparently failed to appreciate this fact with regard to material com-

FIG. 13.—Individual plant of *Medicago falcata*, S. P. I. No. 24455, a medium broad crowned plant of ascending habit of growth, representing Group III.

ing under their observation, as otherwise they doubtless would have refrained from describing hybrids as species or varieties.

It has been possible to find among the department's introductions and selections forms that answer to the description of most of the varieties of *Medicago falcata* and *Medicago sativa* that have been proposed by botanists. That many of these forms are hybrids is quite clearly indicated by the fact that their progeny even from one generation of self-fertilized seed breaks up in a manner characteristic of hybrids. Furthermore, certain of the so-called varieties have been created as a result of artificial crossing, and there is abundant reason to believe that a great many of them can be origi-

nated in this way. The extensive living collection of alfalfas which the department has in its possession furnishes an opportunity for studying the variations that is not afforded by the herbaria of the country and makes it possible to gain a conception of the group as a whole that can not be gained from a study of dried material.

Partial lists are given here of the botanical names that have been applied to what appear to be forms of true *Medicago falcata*, to hybrids of *Medicago falcata* and *Medicago sativa*, and to species and varieties whose origin and relationship to *Medicago falcata* are not clear, together with a brief description of the forms in question. The localities in which the various forms were collected are in most cases indicated in the descriptions.

FIG. 14.—Individual plant of *Medicago falcata*, a somewhat coarse stemmed, ascending form, probably introduced from India, representing Group III.

Botanical names that have been applied to what are apparently true forms of Medicago falcata.

M. procumbens Bess. (*9*).[1]

Pods falcate, nearly smooth; stipules dentate at the base; leaflets oblong, dentate at the apex; stems procumbent; flowers golden; mature pods falcate. Locality: Lemberg and Cracow.

M. intermedia Schultes (*54*).

Stems procumbent; pedunçles corymbose-racemed; pods falcate, slightly pubescent; stipules sagittate; leaflets linear, obcordate, apex slightly serrulate; flowers yellow. Locality: Galicia.

M. falcata pratensis Boenn. (*11*).

Diffuse; leaflets linear-cuneate, narrow, clearly dentate at the apex, truncate; racemes short. Locality: Munster, Germany.

[1] The numbers in italic refer to "Literature cited," pp. 67–70.

M. falcata riparia Boenn. (*11*).

Stems large, erect; leaflets very large, oblong, dentate at the apex, slightly truncate; racemes elongated, many flowered; flowers large. Locality: Munster, Germany.

M. falcata montana Boenn. (*11*).

Stems slender, filiform, decumbent; leaflets small, linear-truncate, slightly dentate; racemes few flowered, capitate; flowers one-half as large as *M. falcata pratensis*. Locality: Munster, Germany.

M. falcata minor Gaud. (*22*, p. 611).

Pods falcate or once coiled. Locality: Vicinity of Sierre, Switzerland.

FIG. 15.—Individual plant of *Medicago falcata*, S. P. I. No. 20719, a form of very leafy, erect habit, very desirable from a forage standpoint, typical of Group IV.

M. falcata stenocarpa Reich. (*49*).

Pods semicircular, narrower than those of ordinary *M. falcata*, diameter of the arc 3 lines, width 1 line. Locality: Not specified.

M. falcata major Koch (*29*, p. 160).

Stems elongated, procumbent; stipules larger than those of ordinary *M. falcata* and more dentate. The author cites *M. procumbens* Bess., and *M. intermedia* Schultes, as synonyms. Locality: Not specified.

M. falcata major prostrata Koch (*30*).

Stems 2 feet long, prostrate; stipules strongly toothed; flowers proportionately large and bright yellow. Locality: Germany.

M. falcata procumbens Ledeb. (*35*).

Stems long, prostrate; stipules foliaceous, semisagittate; flowers larger than those of ordinary *M. falcata;* pods less arched, more unequal, almost smooth. Locality: Volhynia, Podolia, and Bessarabia, Russia.

M. falcata genuina Godron (*25*).

Flowers vivid yellow; pods falcate. Locality: Environs of Nancy, France.

M. falcata typica Trautv. (*61*).

Flowers yellow; pods falcate or semicircular. Locality: Ajagus, Siberia.

M. falcata diffusa Schur (*55*).

Stems slender, diffuse; secondary branches short, erect; leaflets very small, obovate-oblong; flowers smaller than those of *M. falcata major* of Koch, yellow; pods falcate, smooth. Locality: Salzburg and Kolos, Hungary.

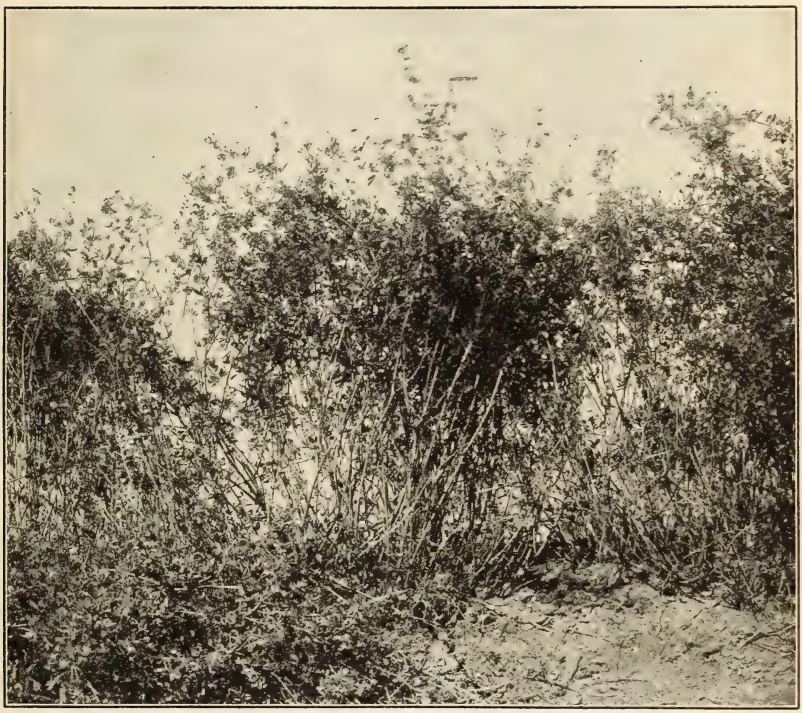


FIG. 16.—Individual plant of *Medicago falcata*, S. P. I. No. 30433, a very upright, somewhat coarse form which can be easily harvested by the ordinary hay machinery, representing Group IV.

M. falcata alpignea Schur (*55*).

Slightly shrubby, very branching; leaflets very small, obovate, mucronate at apex; pods semicircular or falcate, slightly pubescent. Locality: Transylvanian Alps.

M. sativa falcata Alefeld (*1*, p. 75).

Stems prostrate; leaflets ½ inch long by 2½ lines broad; flowers yellow; pods falcate to nearly circular, making from one-fourth to 1 coil. Locality: Germany and Austria.

M. falcata suberecta Lindm. (*37*).

Stems ascending, erect; pods falcate or semicircular. Subvar. 1.—Smoother, leaves broader. Subvar. 2.—More hairy, leaves narrower. Locality: Elizavetgrad, Russia.

M. falcata microphylla Cusin and Ans. (*16*).

No description is given of this plant, but judging from the illustration it is very slender; apparently prostrate; leaflets small, narrow, truncate, toothed at the apex; pods rather broad, falcate or nearly straight. Locality: Not specified.

M. falcata gracilis Urban (*62*, p. 56).

Racemes 1 to 5 flowered; leaflets only 3 to 5 mm. long; flowers yellow; pods straight or sickle shaped. Locality: Not indicated.

M. falcata aurea Schur (*56*, p. 171).

Flowers golden yellow; pods with short, soft hairs; leaflets obovate-obcordate, toothed at the apex; stems ascending or procumbent. Locality: Austria.

M. falcata pauciflora Lindm. (*36*).

Racemes more open than those of ordinary *M. falcata;* peduncles few (1–4) flowered; flowers small; leaflets very narrow; pods falcate. Locality: Near Odessa, Russia.

M. falcata aureiflora Rouy and Foucaud (*51*, p. 11).

Pods pubescent; flowers golden, almost orange. Locality: Not specified.

M. falcata pubescens Rouy and Foucaud (*51*, p. 11).

Pods pubescent, sometimes almost glabrous; flowers yellow. Locality: France.

Botanical names that have been applied to what are apparently hybrids of Medicago falcata and M. sativa.

M. varia Martyn (*43*, p. 87).

Flowers variegated, showing yellow, green, white, blue, purple, and black; stipules narrower than those of *Medicago sativa*. Locality: Not indicated.

M. media Persoon (*48*).

Peduncles slightly corymbose; flowers pale blue, finally becoming golden yellow; leaflets linear-cuneate, dentate at the apex; pilose below. Locality: Not indicated.

M. falcata versicolor Wallr. (*65*).

Flowers pale blue, finally becoming yellow. Locality: Trotha and Bittendorf, Germany.

M. sativa versicolor Ser. Mss. (*57*, p. 173).

Flowers yellow and blue; equals *M. falcata versicolor* of Wallr., Sched. Crit. Locality: Not specified.

M. falcata hybrida Gaudin (*22*, p. 611).

Flowers pale blue, finally becoming green and yellow. Locality: Nyon, Switzerland. (Gaudin, Flora Helvetica, 1829, v. 4, p. 611.)

M. sativa hybrida Gaudin (*22*, p. 612).

Flowers yellow. Locality: Nyon, Switzerland.

M. falcata tumida Ser. (*57*, p. 172).

Flowers swollen; stamens coalescing to the swollen, slightly fleshy, abortive carpel. Locality: About Geneva. This description would seem to indicate that these flowers are abnormal, in which case the plant is probably a hybrid, as hybrid plants having flowers of similar character have been observed in a number of instances.

M. sylvestris Fries (*21*, p. 92).

Peduncles racemed; banner of corolla oblong, with dark-green striations; pods circular or semicircular. Locality: Skanes, Gothland, and Oland, Sweden. This name is intended by the author to cover all forms of *Medicago falcata* × *sativa*.

M. sativa decolorans Fries (*21*, p. 91).

Stems somewhat decumbent; leaflets often narrower than in ordinary *Medicago sativa;* petals violet, becoming a dirty yellow or finally the color of iron stain. Locality: Southern Sweden.

M. pauciflora Ledeb. (*35*).

Pilose; racemes few (2–4 flowered); pods smooth, spirally coiled; pedicels less than half the length of the calyx, erect after flowering; leaflets cuneate, denticulate at the apex; flowers yellow. Locality: Barku Province, Russia. The author places this plant in a group including plants of white, yellow, blue, and violet flowers.

M. sativa versicolor Koch (*29*, ed. 2).

Flowers bright yellow, changing to green, and later into pale violet. Locality: Not specified.

M. sativa albiflora Babey (*3*).

Flowers pure white. Locality: Environs of Montbeliard, France. Rouy and Foucaud describe this variety as having pubescent pods and whitish flowers.

M. falcata ambigua Trautv. (*61*).

Flowers violet; pods falcate, semicircular or circular. Locality: On the shores of Lake Alkaul, Siberia.

M. sativa atriflora Alefeld (*1*, p. 76).

Like *Medicago falcata* in character of growth and pods, but the flowers on opening are blackish blue. Locality: Not indicated.

M. sativa kochiana Alefeld (*1*, p. 76).

Like *Medicago falcata*, but the flowers are at first yellow, then green, and at last violet. Locality: Not indicated. According to the author, this equals *M. falcata bicolor* of Koch and *M. falcata hybrida* of Gaudin.

M. sativa intermedia Alefeld (*1*, p. 76).

Like *M. sativa kochiana*, but with larger stems, larger and more toothed stipules, and larger flowers. Locality: Not indicated. Alefeld gives this as equal to *M. intermedia* Schultes, *M. procumbens* Besser, and *M. falcata major* of Koch, but from the description it is quite apparent that the plants are very different.

M. sativa rotundifolia Alefeld (*1*, p. 75).

Stems erect; the lower leaflets circular, 5 lines long by 4½ lines broad, the upper ones slightly oblong, 5 lines long and 3 lines broad; bloom bluish yellow; stipules with hairlike serrations, whereas those of the other varieties are short but sharp toothed. Locality: Ladak in Tibet

M. sativa tibetana Alefeld (*1*, p. 75).

Stems ascending, slender; leaflets 8 lines long and 3 lines broad: flowers yellowish blue; pods with 1 to 2½ coils. Locality: Himalayas.

M. sativa pallida Alefeld (*1*, p. 76).

Stems prostrate like *M. falcata;* leaflets 6 lines long by 3 lines broad; bloom light yellow, somewhat larger than ordinary *M. falcata;* pods with 1 to 1⅓ coils, with an open center 1½ lines wide. Locality: Not indicated.

M. sativa rosea Alefeld (1, p. 75).

Stems erect and similar to *M. vulgaris;* leaflets 8 lines long, 4 lines broad, rather large; flowers bright rose color. Described from a dry specimen. Locality: Not indicated.

M. subfalcata Schur (*55*).

Leaflets obovate-linear; stipules very long acuminate; flowers capitate, variegated, pale yellow at first, changing to green, and finally becoming a dirty violet; pods smooth, forming one coil. Locality: Vicinity of Kronstadt, Hungary.

M. falcata sativa Schur (*55*).

This is given as equal to *Medicago subfalcata* of Schur.

M. lilacea Hy (*27*, p. 432).

Stems prostrate; branches elongated; flowers violet; pods falcate or forming a complete circle. Locality: River Loire, France.

M. spuria Hy (*27*, p. 431).

Stems robust, decumbent; flowers variegated, yellow and violet, deciduous after flowering; the few pods that are formed usually having two coils. Locality: River Loire, near Ponts-de Ce, France. The author states that this is a hybrid of *M. cyclocarpa* and *M. sativa*.

M. cyclocarpa Hy (*27*, p. 431).

Stems prostrate; flowers golden yellow or finally variegated with blue or violet; pods coiled, forming about one spiral. Locality: River Loire, between Laumur and Nantes, France.

M. varia pseudosativa Rouy and Foucaud (*51*, p. 14).

Pods large, glabrescent. Locality: Alpes-Maritimes, France. According to the authors, this is a hybrid of *M. sativa* and *M. falcata*, resembling the female parent and equaling *M. spuria* of Hy.

M. varia pseudofalcata Rouy and Foucaud (*51*, p. 15).

Pods large, glabrescent, with one coil. Locality: Alpes-Maritimes, France.

M. silvestris erectiuscula Rouy and Foucaud (*51*, p. 12).

Stems ascending; corolla yellow, not variegated; pods generally semicircular, glabrescent, or glabrous. Locality: Not specified.

Botanical names that have been applied to species and varieties whose origin and relationship to M. falcata are not clear.

M. glomerata Balbis (*5*).

Pods coiled, hairy; stems erect; leaflets and flowers very much like those of the ordinary *Medicago falcata;* pods glomerate, villous; corolla yellow. Locality: Nice, France.

M. falcata annularis Ser. (*57*, p. 172).

Leaflets narrower and smaller than in ordinary *Medicago falcata;* pods very much arched, almost spiral. Locality: Not indicated.

M. procumbens viscosa Reich. (*49*).

Pods falcate, glandular viscous; flowers bright yellow; seeds 2 to 6. Locality: Saxony, near Dresden.

M. annularis Bess.

This plant is usually referred to as equaling *M. falcata annularis* of Seringe. Besser's description was not available, and it is doubtful whether it was ever published. Koch (*30*) states that he has seen a specimen from Besser in Schultes's collection. Other authors refer to a description of *M. annularis* in Besser's Prim. Fl. Gal. (*9*), but this is evidently an error, as no reference is made to such a plant in that work.

M. falcata glandulosa Koch (*30*).

Pods with scattered, articulated hairs, which are provided with a gland at the end. Locality: Not specified.

M. falcata viscosa Urban (*62*, p. 57).

Pods glandular haired, straight or sickle shaped; flowers yellow. Locality: Not indicated.

M. glandulosa procumbens Schur (*56*, p. 172).

Flowers golden yellow, in loose racemes; pods more or less falcate or almost straight, with inflated glandular hairs; stems prostrate. Locality: Spielberg, Austria.

M. falcata laxiflora subscandens Schur (*56*, p. 172).

Stems weak, climbing among bushes, branching above; leaflets obovate-lanceolate, slightly hairy, toothed at the apex; stipules long, linear-lanceolate, as long as the leafstalk; flowers pale yellow, in loose capitate clusters; pods variously formed, more or less sickle shaped, inflated, glandular haired. Equals *Medicago laxiflora* Schur. Locality: Vicinity of Brunn, Austria.

M. falcata albida calciola Schur (*56*, p. 172).

Flowers white or yellowish white; pods almost smooth or somewhat glandular haired; stems upright; leaflets long to cuneate, slightly grayish green. Locality: Vicinity of Vienna and Brunn, Austria.

M. varia pseudoglomerata Rouy and Foucaud (*51*, p. 15).

Pods somewhat smaller than in ordinary *M. sativa*, glandular pubescent, with 1 to 2 coils. Locality: Alpes-Maritimes.

M. silvestris glandulosa Rouy and Foucaud (*51*, p. 13).

Pods more or less glandular pubescent. Locality: Not specified.

AGRICULTURAL HISTORY.

As far back as mention of *Medicago falcata* can be traced in the history of agriculture it has almost invariably been referred to directly or indirectly as a noncultivated species. Incidentally it may be inferred from certain references by early writers that the plant was utilized in a very limited way for forage in some localities in Europe, but no hint is given that it was cultivated there for that or any other purpose. No attempt has been made to search the literature for information regarding its early utilization in Asia.

The species was at least sufficiently well known to be mentioned in European literature more than three centuries ago, but up to the time of Linnæus (1750–1790) no botanists or agriculturists apparently had ever recommended its domestication. About 1783 Le Blanc (*32*) became interested in the plant, which he termed "Yellow Medick," on account of its ability to produce a good growth on poor soil. He conceived the idea of its domestication, but in the course of his investigations his attention was attracted to a hybrid of *Medicago sativa* and *Medicago falcata*, to which he gave the name "Variegated Medick." In his opinion, this plant was superior to either the common lucern or the yellow medick, and therefore he discontinued his efforts to domesticate the latter.

The literature of the past century contains many references to the cultivation of *Medicago falcata*, but outside of limited localities in India, China, and southern Russia, where it is reported to be cultivated to some extent, it is not grown under cultivation except for experimental purposes. It is a significant fact that regardless of the relationship of *Medicago falcata* to common alfalfa, the early recognition of its value, and the numerous attempts to domesticate it, the plant is still an uncultivated species. However, it must be said that

it is probably utilized at the present time more than ever before in Europe and Asia, but wholly as a wild plant on the ranges and in pastures. According to Hansen (*26*, p. 12), it is attracting attention as a range plant in European Russia. Meyer is authority for the statement that the Kalmucks and Sarts in Chinese Turkestan gather it, together with other wild plants, as hay for horses and cattle. Nilsson indicates that it is utilized quite abundantly in Sweden as a wild pasture plant on dry, sandy land. It is reasonable to conclude, therefore, that its value has long been recognized in the agriculture of Europe and Asia. Farther on in this paper some of the reasons for its present agricultural status will be discussed.

COMMON NAMES.

While various common names have been applied to *Medicago falcata*, unfortunately there is none that is without somewhat serious objections. The most satisfactory name that suggests itself and the one that is most commonly used in this country is "yellow-flowered alfalfa." The chief objection to this name lies in the fact that it is not distinctive, there being other fairly distinct species of Medicago belonging to the alfalfa group that have yellow flowers. However, *Medicago falcata* is the most promising member of the yellow-flowered group from a forage standpoint, and it is quite probable that the common name "yellow-flowered alfalfa" will be generally adopted for it. The name "sickle-podded alfalfa" has been occasionally used, but it is cumbersome and harsh sounding. "Siberian alfalfa" meets with objections because the species is by no means confined to Siberia in its natural range. Meyer[1] writes that—

> In the southern and central Provinces of Russia and more especially along the Volga River, this wild lucern is called Burgoon. In western Siberia a number of names are in use among the farmers, like Sholty lucern, Sholty klever, Sholty weeseel, and Deekii lucern. These mean, respectively, yellow alfalfa, yellow clover, yellow vetch, and wild alfalfa. The second name, however, applies also to various species of Melilotus, while the third one is given to *Lathyrus pratensis*. The German settlers in the Caucasus in southern Russia and in western Siberia call this wild alfalfa invariably "steinklee," meaning stone clover, or if one gives the word stein a wider meaning, wild clover. In Chinese Turkestan the Turki people call this plant "Tagh-beda," and it seems very likely that the Germans have simply translated this name, since these hardy and industrious settlers have always come much in contact with Tartars and Kirghiz, who all speak Turki dialects. The Dsungans, in Chinese Turkestan, who are Chinese who have become Mohammedans, give *Medicago falcata* the name of "San musu," which means mountain alfalfa or wild alfalfa. The name "musu" is, however, applied to several trifoliate plants in the same way the average person uses the word clover for many widely dis-

[1] In an unpublished report on file in the United States Department of Agriculture.

tinct plants. In the regions around Semipalatinsk on the Irkutsk River in southwestern Siberia where this *Medicago falcata* is especially abundant, the Kirghiz and Russian settlers alike call it "sholteek" and it is this name that the writer proposes to give to the plant. This name "sholteek" is probably a Kirghiz corruption of two Russian words and means something yellowish. Now, however, in the vicinity of Semipalatinsk, this word is being applied apparently exclusively to *Medicago falcata*.

Meyer offers three reasons why the name "sholteek" should be used in preference to other names: (1) That it consists of a single word only; (2) that it is easy to pronounce, easy to remember, and has a pleasing sound; (3) that it is already in use over a large area in Asia, where *Medicago falcata* grows in its greatest abundance. While the name "sholteek" is a somewhat pleasing one and not very difficult to pronounce, it is very doubtful whether any name that does not include the name alfalfa will ever be generally adopted in this country. The names "Orenburg alfalfa" and "Semipalatinsk alfalfa" have been applied to mixed lots of seed introduced from Provinces in Russia and Siberia having these names. The following is a list of some other common names that have been applied to the species, none of which appears to be acceptable (*53*):

Svensk Lucern, Fodorsmare, Gul Lucern, Kosmor, Linne's hofro, Ljungpinnar, Rast, Refgras, Refvagras, Svensk Smare, Deutsche Luzerne, Grosser Steinklee, Schwedisches Heu, Schwedischer Heusame, Schwedische Luzerne, Sickelklee, Spargelklee, Wildes heiliges Heu, Butterjags, Horned Clover, Sickle-podded Medick, Yellow Lucern, Luzerne de Suede, Luzerne faucille, Luzerne Jaune, and Luzerne sauvage.

AGRONOMIC CHARACTERISTICS.

From an agronomic standpoint *Medicago falcata* does not resemble *Medicago sativa* as closely as its botanical relationship would indicate. Habit of growth as regards suitability for hay or pasturage, quantity of growth as indicated by the production of profitable yields under various conditions of soil and climate, and quality of growth or herbage as interpreted in terms of palatability and feeding value are agronomic characteristics that in the main bear little relationship to diagnostic botanical characters. However, no sharp line exists between these two sets of characters, as may be readily seen, for example, in the case of the production of seed. The quantity of seed produced and its retention by the plant are characteristics of considerable botanical as well as agronomic significance.

It is in the agronomic characteristics alone that the farmer is interested, and to a very large degree the plant breeder likewise, since production is the practical end which both must always keep in view. A careful study of the characteristics of the plant which relate directly to its utilization as a forage crop, then, is of the utmost importance. Since most of the agronomic data presented herewith were

secured, a number of promising forms have been obtained from India. The data and conclusion, therefore, do not necessarily apply to these late introductions. Their behavior strongly suggests the advisability of deferring judgment on them until they have been more thoroughly tested.

GENERAL HABITS OF GROWTH.

There is a wide range of variation of growth in plants of *Medicago falcata*. Practically every degree of erectness is represented, from prostrate to upright. However, from a forage standpoint the species may be divided into two general groups—the procumbent, prostrate, or spreading group, which, theoretically at least, has some advantages over the upright forms for pasturage, and the ascending or suberect group, which is suitable for hay production. Oliver (*47*) has discussed the pasture forms in some detail. A large majority of the forms fall either in the so-called pasture group or are not sufficiently erect to be included in the hay group. The apparently prevalent opinion, however, that there are no upright forms is erroneous, since there are some quite as erect as any that can be found in *Medicago sativa*. The degree of erectness, it is true, is influenced to some extent by cultural methods. The habit of the plants is dependent to a considerable degree upon whether they are grown in hills, widely spaced rows, or in broadcast stands. In hills and in rows they are much more procumbent than when grown in broadcast stands. However, thickness of planting does not overcome the decumbent habit of the plants in groups 1 and 2 sufficiently to permit harvesting by machinery without loss. Observations made at Brookings, S. Dak., on two tenth-acre broadcast plats seeded in 1909 indicate an appreciable improvement in the degree of erectness of the plants after the stand becomes thickened by the enlarging of the crowns, which was especially noticeable after the second or third year of growth.

The forms suitable for hay, so far as the matter of harvesting is concerned, are confined almost exclusively to groups 3 and 4. These forms are found abundantly in S. P. I. Nos. 20718, 20719, 24455, 26927, 28070, 28071, 30433, and 32412. (See figs. 12, 13, 14, and 15.) The extremely low, spreading pasture forms are found in groups 1 and 2, and especially in S. P. I. Nos. 20717, 20725, and 24454, where they predominate. (See figs. 7, 8, and 9.)

CHARACTERISTICS OF THE VEGETATIVE GROWTH.

The general appearance of the vegetative growth of the upright forms of *Medicago falcata* is not materially different from that of *Medicago sativa*, except that it is somewhat more silver gray in color. The mass height in broadcast stands is commonly less than that of

Medicago sativa, although in a few of the erect forms there is comparatively little difference in this respect. From a similar stand of the same height of mass growth *Medicago falcata* will produce a heavier yield than *Medicago sativa*, partly because of the thicker growth of stems and partly because of the texture of the herbage. Estimates of yields based upon appearance therefore commonly err in favor of *Medicago sativa*. Conditions of soil and stand being equal, individual cuttings of the best upright forms of *Medicago falcata* frequently outyield those of varieties of *Medicago sativa*.

A characteristic of considerable importance in any hay crop is the proportion, by weight, of leaf to stem. The plants of *Medicago falcata* show great variation in this respect, making the character of little value in any system of classification. However, in the very low forms the proportion is greater than in the more erect ones. A critical study of 27 S. P. I. introductions indicates that the leaves compose from 34.5 per cent to 67.5 per cent of the total dry weight of the herbage. The highest percentage of leaves was found in group 1 in plants of S. P. I. Nos. 20717 and 20725. McKee (*42*) presents data on the percentage of leaves by weight for three varieties of *Medicago sativa*, as follows:

Peruvian	52.5 per cent.
Arabian	56.4 per cent.
Common (Utah grown)	49.8 per cent.

According to the investigations of the Utah Agricultural Experiment Station (*67*) the percentage of leaves by weight in common alfalfa ranges from 22.7 to 38.4, depending upon the stage of maturity. It is safe to assume that the erect forms of *Medicago falcata* are not essentially different from the common varieties of *Medicago sativa* with respect to the above character. The leaves of the former, however, are retained after curing to a greater degree than those of the latter, which is a very important factor.

STEM CHARACTERISTICS.

The size and number of stems of the plant vary greatly with its habit of growth. (Fig. 17.) In the very procumbent or prostrate plants the stems usually are finer and more abundant than in the more erect ones. An actual count made on plants 4 years old indicates the number of stems to range from 292 in S. P. I. No. 20718, a large ascending form, to 1,682 in S. P. I. No. 20717, a broad-crowned form. Plants of Turkestan alfalfa of the same age and grown under similar conditions had approximately 225 stems per plant. In this agronomic character also *Medicago falcata* compares very favorably with *Medicago sativa*.

PERIODS OF GROWTH.

Observations made at Brookings in 1912, 1913, and 1914 indicate that *Medicago falcata* has a tendency to commence growth earlier in the spring than *Medicago sativa* or *Medicago sativa* × *falcata* hybrids. This characteristic is apparently influenced by climatic and soil conditions. If, as frequently happens in early spring, a short period favorable for growth is followed by continued cool or cold weather, the difference between the quantity of growth of *Medicago falcata* and *Medicago sativa* when the growing season really begins is very noticeable. This probably is due to the fact that while both may

FIG. 17.—Loose bunches of stems of various forms of *Medicago falcata*, showing general types of growth.

start during the favorable period, the former is able to outgrow the latter during the unfavorable period following.

At Highmore, S. Dak., in the spring of 1912, *Medicago falcata* continued growth throughout an extended period of very cold weather, while *Medicago sativa* made very little growth. The same phenomenon was observed at Brookings, but the difference between the two was not so pronounced. In the spring of 1914 the difference in the earliness of growth was less noticeable than in the other seasons mentioned. The soil was extremely dry until well into April that year, after which the conditions of warmth and moisture were unusually favorable, resulting in good growth of all varieties. It seems reasonable that the lack of difference between the spring growth of *Medi-*

cago falcata and *Medicago sativa* in this instance may have been due to these conditions, particularly to the dryness of the soil.

The various forms of *Medicago falcata* exhibit slight differences in the earliness of spring growth. It seems to be true that young plants of all alfalfas start growth earlier than old plants. Therefore, only plants of the same age should be compared in making observations on this point.

In his discussion of Peruvian alfalfa, which he describes as *Medicago sativa* variety *polia*, Brand (*12*) calls attention to the ability of this strain to continue growth during the late fall and winter when other varieties of *Medicago sativa* become dormant on account of the low temperature. The term "zero point" is applied by him to the minimum temperature at which growth can be made. He consequently classes Peruvian alfalfa as a variety which has a low zero point and common alfalfa as a variety with a comparatively high zero point. Brand's observations were made in southern Arizona, and had *Medicago falcata* been studied in comparison with the varieties of *Medicago sativa* it doubtless would have been considered as having the highest zero point of all, since it discontinues growth in the Southwest earlier than any of the other varieties of alfalfa.

A study of the various alfalfas at different latitudes with regard to their phenological characteristics reveals some rather interesting and important points. The most important of all, perhaps, is the effect of severely low temperatures on their so-called zero points of growth. This can be explained best by citing the behavior of the distinct forms in different parts of the country. In California and the far Southwest, McKee finds it readily possible to distinguish Peruvian alfalfa, common alfalfa, *Medicago sativa* × *falcata* hybrids (the general group of variegated alfalfas), and *Medicago falcata* by their growth in late fall and early spring, without regard to their morphological characters. They discontinue growth in the fall and resume it in the spring in the order in which they are named above. The same order obtains in general at the Arlington Farm, Va., with some seasonal variation, but at Brookings and Highmore there is a tendency toward the reversal of this order. The latitude of Washington, D. C., appears to be about the dividing line, if high altitudes are excepted.

SPRING GROWTH.

Westgate (*66*) in discussing *Medicago falcata* × *sativa* hybrids says, "in earliness of starting in spring as well as in earliness in blooming, the variegated alfalfas appear to exceed the ordinary kinds." He qualifies this statement somewhat by saying "In the southern one-half of the United States the variegated alfalfas are

normally later in starting than the ordinary variety." This indicates possibilities worth considering in the development of new agronomic strains of alfalfa through the hybridization of *Medicago sativa* and *Medicago falcata*. It seems quite probable that severely low temperatures materially influence the ability of varieties to commence growth in the spring. In the colder and drier portions of the Great Plains area a variety of alfalfa making a growth in the early spring is more certain of producing a good crop of hay than those that are slow in starting, as it is able to take advantage of the winter moisture. Since one good cutting is sometimes all that can be obtained, the ability of a variety to produce early spring growth is of considerable importance. *Medicago falcata* not only possesses this characteristic, but is able to transmit it in some degree to the progeny resulting from its hybridization with *Medicago sativa*.

In May, 1915, the effects of the five severe frosts and freezes which occurred during that month were observed on the nursery rows at Redfield, S. Dak. The rows of *Medicago falcata* showed decidedly less damage than the adjoining rows of *Medicago sativa*. It is true that the plants of the former, being of lower growth than those of the latter, may have received some protection from the earth. With the exception of the introductions from India, S. P. I. Nos. 26927, 29139, and 30433, the *Medicago falcata* plants showed almost no frost effect, while those of *Medicago sativa* were badly wilted. The effect of the frost was apparently the same on the Grimm, Canadian variegated, Baltic, Turkestan, and local Dakota strains.

RECOVERY AFTER CUTTING.

A characteristic wherein *Medicago falcata* differs materially from *Medicago sativa* is in rate of growth after cutting. The ability to produce several crops of hay in a season under favorable conditions has been largely responsible for the popularity which the latter has had for centuries. Unfortunately, the former does not possess this ability to any considerable degree: in fact, only under very favorable conditions can more than one good cutting be procured from it.

Table II indicates the comparative rate of recovery of *Medicago falcata* and *Medicago sativa* after cutting at Brookings.

TABLE II.—*Comparative rate of recovery of Medicago falcata and Medicago sativa after cutting, at Brookings, S. Dak., in 1913.*

Plants cut June 19.	Height of growth—	
	July 8.	July 22.
	Inches.	*Inches.*
Medicago falcata, seven introductions	4 to 9	8 to 13
Medicago sativa, two strains	16	19 to 20

The above data are verified by those obtained at Highmore, where plants grown in hills 44 by 44 inches were cut and the recovery noted. A brief summary of the results is presented in Table III.

TABLE III.—*Rate of recovery of Medicago falcata after cutting, at Highmore, S. Dak., in 1913.*

S. P. I. No.[1]	Average measurement of plants.		Date harvested.	Average height on July 17.	S. P. I. No.[1]	Average measurement of plants.		Date harvested.	Average height on July 17.
	Height.	Spread.				Height.	Spread.		
	Inches.	*Inches.*		*Inches.*		*Inches.*	*Inches.*		*Inches.*
20717	12⅛	35⅜	June 27	3½	20725	12½	36½	June 27	4½
20718	21	45½	June 23	7½	24452	17½	43½	June 24	6⅜
20721	18¾	39½	June 14	7½	28070	23½	41½	June 24	7⅜
20722	19	35¼	June 17	7	28071	20⅜	44	June 23	4⅜

[1] Observations were made on eight plants of each number.

As will be noted, there is some difference in the rate of recovery of the various introductions, but this ordinarily is small and can scarcely be considered as a fixed characteristic of any of the forms. Observations made on plats where strains of *Medicago falcata* were grown in broadcast stands indicate that the growth after cutting is less than when grown in rows and hills. The specific data herein recorded are supported by general data published by the Dickinson (N. Dak.) substation (*64*) and in reports of the Canadian Experimental Farms (*41*).

LATE AUTUMN GROWTH.

The difference in the comparative rate of growth of *Medicago falcata* and *Medicago sativa* in the autumn is influenced to a great extent by temperature. In October, 1913, notes were taken at Brookings on the effect on the various alfalfas of a hard freeze that occurred September 22, when the temperature reached 17° F. In general, the plants of *Medicago falcata* were little affected, and nearly all that were recorded then as being injured were later found to be hybrids of *Medicago falcata* and *Medicago sativa*. The various strains of *Medicago sativa* were very noticeably injured, while the hybrids were also injured, but to a somewhat less degree.

In a season of relatively high fall temperatures and favorable moisture conditions plants of *Medicago sativa* will produce more late fall growth than those of *Medicago falcata*. This is quite in accordance with the previous discussion under "Spring growth."

HARDINESS.

The characteristic of hardiness in plants is commonly defined as ability to endure cold. It has recently, however, come to have a broader meaning; namely, the ability to survive winter conditions.

Among the factors influencing winterkilling may be mentioned low temperature, excessive variation in temperature, protection as afforded by snow and drifted soil, thickness of stand of plants, precipitation, vigor of plants upon entering the winter, and condition of soil with respect to moisture, surface drainage, and existence of ice sheets.

Medicago falcata is generally regarded as a hardy species, and it was for this reason that efforts were made to introduce as many of its forms as possible from regions where it is found growing naturally. While it scarcely could be expected that forms of the species from the Mediterranean region would be as hardy as those from the vicinity of Yakutsk, 62° north latitude, where the temperature reaches —84° F., it is probable that most of the forms can be placed in the class of comparatively hardy alfalfas, regardless of the geographical location in which they were developed. Just why some varieties of alfalfa are more susceptible than others to winter conditions is not clearly understood. It is now commonly believed, however, that an important factor in the hardiness of any variety is the degree of protection which the plant provides its dormant or resting buds. For example, varieties in which the crowns are produced well above the surface of the ground are uniformly tender, while those in which the crowns are near or beneath the surface are mostly hardy. The Arabian and Peruvian varieties may be cited as illustrations of the former, while the Grimm and Baltic varieties represent the latter group. The dormant buds of the varieties with high crowns are fully exposed to the unfavorable conditions of winter, while those of the varieties having low crowns are protected by the soil, and to some extent by the dead herbage of the preceding summer. The relation of deeply set crowns to hardiness probably was first called to attention in agricultural literature by Thomas Le Blanc in 1791 (*32*), but it is only within recent years that the significance of this characteristic of the crown has been duly appreciated (*45*, p. 4).

A majority of the forms of *Medicago falcata* produce at least a part of their new growth from underground members, either rhizomes or true lateral roots, a characteristic which affords material protection during periods of severe conditions. It is largely upon this feature, as well as upon its geographical range, that the estimate of its hardiness has been based.

While comparative tests of the hardiness of *Medicago falcata* and strains of *Medicago sativa* grown in rows and hills have been made since 1910, there are still insufficient critical data from which to draw definite conclusions as to the relative hardiness of the former under actual field conditions. Unfortunately, many of the plantings that were made in 1909 were poorly provided with checks and did not

include the common commercial strains of *Medicago sativa* to a sufficient extent. Nevertheless, the results from these and other plantings go far toward proving the hardiness of *Medicago falcata.*

In the fall of 1910, counts were made of plants of one variety of *Medicago sativa*, three hybrid strains, and several numbers of *Medicago falcata* at Brookings and Highmore. At the former place the plants were grown in hills 24 by 36 inches, and at the latter in hills 44 by 44 inches. The following spring, counts were made to determine the percentage of plants that survived the winter, with the results shown in Table IV.

TABLE IV.—*Comparative winterkilling of Medicago falcata and Medicago sativa*[1] *grown at Brookings and Highmore, S. Dak., 1910–11.*

Species.	S. P. I. No.	Brookings.			Highmore.		
		Living plants.		Surviving.	Living plants.		Surviving.
		November, 1910.	April, 1911.		November, 1910.	April, 1911.	
				Per cent.			*Per cent.*
Medicago sativa	20711	238	231	97.0	112	15	13.3
Medicago sativa × Medicago falcata	20571	256	252	98.4	119	85	71.4
Do	20714	497	488	98.1	111	18	16.2
Do	20716	298	287	96.6	74	20	27.0
Medicago falcata	20717	265	264	99.6	355	344	96.0
Do	20718	318	305	95.9	148	144	97.3
Do	20719	245	242	98.7	323	323	100
Do	20720	65	65	100			
Do	20721	261	257	98.4	350	297	84.8
Do	20722	250	244	97.6	286	245	85.6
Do	20724	39	39	100			
Do	20725	259	259	100	354	334	94.3
Do	20726	311	311	100			
Do	24452	771	771	100	185	182	98.3
Do	24453	56	56	100			
Do	24454	501	501	100			
Do	24455	322	322	100			
Do	24456	61	61	100			
Average percentage of survival:							
Medicago sativa				97.0			13.3
Medicago falcata × Medicago sativa				97.7			38.2
Medicago falcata				99.2			94.8

[1] The *Medicago sativa* variety used in this test was a selected strain of Turkestan alfalfa. The hybrids were the North Sweden, Cossack, and Cherno varieties.

The minimum temperatures for the winter months at Brookings and Highmore are given in Table V.

TABLE V.—*Minimum temperature (°F.) in each month of the winter of 1910–11, at Brookings and Highmore, S. Dak.*

Locality.	November.	December.	January.	February.
Brookings	5	−16	−32	− 9
Highmore	3	−18	−24	−11

The summary of results at Brookings and Highmore indicates the superior hardiness of *Medicago falcata* at these points, while Table V indicates that factors other than low temperature were responsible for winterkilling.

While the number of plants upon which the percentage of survival shown in Table IV was based is too small to make the data really dependable, the appearance of the plantings at Highmore was very convincing. The rows of Turkestan, North Sweden, Cossack, and Cherno were so depleted as to give the entire block an extremely ragged appearance, while the rows of *Medicago falcata* adjoining had so nearly the full quota of plants that the mass effect remained unbroken. (Figs. 18 and 19.)

Widely spaced hill plantings, such as were made at Highmore, in some respects offer very good opportunity for studying winterkilling, since on such plantings the effect of the important factors is greatly exaggerated. In row plantings and even in broadcast stands at Highmore the mortality of the *Medicago sativa* varieties

FIG. 18.—Hill plantings of *Medicago falcata* varieties, *M. sativa*, and *M. sativa* × *falcata*, commercial varieties and selections. Photographed in August, 1910, Highmore, S. Dak.

was slight, while it was almost negligible in the case of the *Medicago falcata* strains. At Brookings the only winterkilling of *Medicago falcata* which could be considered of any consequence occurred during the season of 1912–13. The mortality in this case was doubtless due to the presence of an ice sheet over a portion of the plats. It is well recognized that Brookings and Highmore are not ideal places at which to test the comparative hardiness of alfalfas; nevertheless, at the latter point winterkilling is a serious factor in common alfalfa under field conditions.

Georgeson (*23*) reports *Medicago falcata* to be the hardiest of all the alfalfas tested in Alaska and that it survives the winter without "inconvenience." His tests, which included the Grimm and other variegated strains, were made under conditions much less severe than those normally obtaining in the Dakotas.

In all the trials which have been reported there is still lack of data on the relative hardiness of the various forms of the species. It now seems probable that this fact will be determined only in-

directly; that is, by determining the relative hardiness of their hybrids with *Medicago sativa*, since many of them are of themselves not of sufficient agronomic importance to justify the expense of extensive tests of hardiness. Several introductions, however, including two lots from India, which have been tested at the University of Saskatchewan, Saskatoon, Saskatchewan, for three or more years, show no perceptible difference in their ability to survive the winter conditions.

Taking into consideration the geographical range of *Medicago falcata*, the provisions made by its various forms for the protection of the buds during the dormant season, and the results of tests in this country and elsewhere, it is fair to assume that the species may well be considered hardy as compared with the commercial strains of *Medicago sativa*. Through this physiological characteristic the various forms of the species will aid in solving the alfalfa problem in the colder and drier portions of the United States.

FIG. 19.—The hill plantings of alfalfa shown in figure 22. Photographed in May, 1911. The solid plantation in the background is of *Medicago falcata* varieties. The scattering plants in the foreground are *M. sativa* and *M. sativa*×*falcata* strains. The difference in winterkilling between the last two and the first was very marked.

DROUGHT RESISTANCE.

Within recent years the relation existing between drought resistance and cold resistance has become more definitely recognized. The adaptations of the plant which make it resistant to cold are now believed to enable it in a large measure to endure or evade drought. The prevailing opinions regarding the drought resistance of *Medicago falcata* have been based chiefly on the fact that it grows naturally in very dry situations and possesses certain characteristics which are ordinarily considered as drought-resisting adaptations. No critical data are available from plants grown under cultivation, but the general results leave little doubt that most of the forms of *Medicago falcata* are relatively drought resistant, and certain forms at least will endure drought conditions too severe for *Medicago sativa*.

The factors that are potent in enabling it to resist drought are its extensive root development, its ability to produce rhizomes well be-

neath the surface of the soil and in certain cases to produce true proliferating lateral roots, and its ability to suspend activity and to lessen transpiration by reducing its leaf surface. During periods of severe drought it makes very little growth above ground, but apparently devotes some energy to the production of rhizomes, from which new growth develops either with the resumption of favorable conditions the same season or in the following spring. This adaptation is of considerable benefit in carrying plants through the critical periods of summer.

The following heretofore unpublished data on the water requirement of *Medicago falcata*, by which is meant the quantity of water required by the species to produce a given amount of dry matter, as determined by the method of Briggs and Shantz, have been furnished by Mr. A. C. Dillman, of the Office of Alkali and Drought Resistant Plant Investigations.

A summary of the water requirement of *Medicago falcata* as compared with that of *Medicago sativa* (the Grimm variety), as determined at Newell, S. Dak., for four seasons, 1912 to 1915, inclusive, and at Akron, Colo., in 1914, is given in the following table:

TABLE VI.—*Comparative water requirement of Medicago falcata and Medicago sativa at Newell, S. Dak., in 1912 to 1915, inclusive, and at Akron, Colo., in 1914.*

Place, year, and species.	Water requirement based on dry matter.							
	Actual.				Relative.			
	First crop.	Second crop.	Third crop.	Combined crops.	First crop.	Second crop.	Third crop.	Combined crops.
AT NEWELL, S. DAK.								
Season of 1912:[1]								
Medicago falcata	622±15	735±18	.....	663±12	89	95	.....	90
Medicago sativa	699±15	772±18	.....	735±15	100	100	.....	100
Season of 1913:								
Medicago falcata	340± 7	713±11	1,220±52	579±12	73	87	109	79
Medicago sativa	469± 6	817±13	1,115±16	735± 8	100	100	100	100
Season of 1914:[2]								
Medicago falcata	503±38	930±26	.....	687±20	93	116	.....	103
Medicago sativa	539	800	.....	669	100	100	.....	100
Season of 1915:								
Medicago falcata	399± 8	424± 4	1,108±20	541± 9	94	103	176	108
Medicago sativa	424± 9	413± 7	630±18	499± 7	100	100	100	100
Mean at Newell:								
Medicago falcata	.....	.....	.....	.....	87	100	142	95
Medicago sativa	.....	.....	.....	.....	100	100	100	100
AT AKRON, COLO.								
Season of 1914:[1]								
Medicago falcata	652±16	757±13	1,201±75	848±27	107	84	114	95
Medicago sativa	610± 3	907±14	1,055±12	890± 6	100	100	100	100
Mean at both Newell and Akron:								
Medicago falcata	.....	.....	.....	.....	91	97	133	95
Medicago sativa	.....	.....	.....	.....	100	100	100	100

[1] The data at Newell, S. Dak., in 1912, and at Akron, Colo., in 1914, were procured from seedling plants, while those obtained at Newell in 1913 to 1915, inclusive, were from plants a year or more old.

[2] At Newell, S. Dak., in 1914 there were five pots of *Medicago falcata*, but only one pot of *Medicago sativa*.

The actual water requirement of the first, second, third, and combined crops for each year is given in the second to fourth columns of the table, and the relative water requirement of each crop, with *Medicago sativa* taken as 100, is given in the last four columns of Table VI. Considering the water requirement of the combined crops, it will be noted that *Medicago falcata* has a slightly lower requirement than *Medicago sativa*. The water requirement of *Medicago falcata*, based on data obtained from 29 separate pots which are summarized in the table, is 663±15, and the water requirement of *Medicago sativa*, as determined from 25 separate pots, is 713±18, or a difference of 50±23 in favor of *Medicago falcata*. This difference, in view of the large probable error, which was in part due to variation in season and location, is not significant. It would appear from the above data that *Medicago falcata* is relatively efficient in its use of water during the early part of the season, but inefficient during the late summer.

There is little doubt that the drought resistance of *Medicago falcata* is quite as high as that of *Medicago sativa*, but it is unlikely that the former can be grown profitably where the latter succumbs. There is a vast agronomic difference between being able to maintain an existence under extremely dry conditions and being able to produce sufficient growth to be profitably utilized for hay or pasture. There is certainly no definite evidence that *Medicago falcata* will be profitable where the better adapted strains of *Medicago sativa* fail.

SEED PRODUCTION.

The seeding habits of *Medicago falcata* are such as to give serious concern in connection with its utilization as a cultivated forage crop. Not only is the quantity of seed produced comparatively small, but a large percentage shatters before it can be harvested by ordinary methods. Even in harvesting by hand the loss of seed through shattering is great. There are no data available on yields of seed under field conditions, but there are numerous data on yields from individual plants, from which estimates can be made of the yields which might reasonably be expected under field conditions.

At Brookings, yields from a large number of plants were recorded from 1910 to 1913, inclusive. The plants were grown in hills 24 by 36 inches, thus providing what are generally considered very satisfactory conditions for seed production. Special care was exercised in harvesting the seed to reduce the shattering to a minimum. Therefore the yield was appreciably greater than if the plants had been harvested by ordinary field methods, and was high also for a fair comparison with *Medicago sativa*.

TABLE VII.—*Alfalfa plants transplanted in 1909 to hills 24 by 36 inches at Brookings, S. Dak., showing yields of seed, 1910 to 1913, inclusive.*

Species.	S. P. I. No.	No. of plants.	Yield of seed per plant (grams).				
			1910	1911	1912	1913	Average.
Medicago sativa	20711	145	2.80	3.70	0.924	1.333	2.188
Medicago sativa × Medicago falcata	20571	248	2.92	4.61	1.506	.709	2.436
Do	20714	418	2.72	3.90	1.108	.641	2.692
Do	20716	263	3.46	6.80	2.231	1.353	3.461
Medicago falcata	20717	261	1.44	.....	.421	.038	.633
Do	20718	243	.35	.084	.352	.181	.241
Do	20719	234	.37	.025	.074	.085	.138
Do	20720	62	.....	.....	.209	.258	.233
Do	20721	159	.205	.126	.477	.157	.241
Do	20722	213	.216	.082	.375	.122	.198
Do	20725	225	1.69	.....	.613	.044	.782
Do	20726	238	1.44	1.22	.586	.247	.873
Do	24452	708	1.28	.135	.405	.210	.507
Do	24454	434	.19	.....	.180	.073	.147
Do	24455	156	.53	.366	.213	.115	.306
Do	24456	59	.....	.....	.205	.169	.187
Do	28070	177	.142	.073	.100	.....	.105
Do	28071	122	.47	.29	.176	.147	.270
Average yield of seed:							
Medicago sativa	.....	.....	.....	.....	.....	.....	2.188
Medicago sativa × Medicago falcata	.....	.....	.....	.....	.....	.....	2.663
Medicago falcata	.....	.....	.....	.....	.....	.....	.347

A summary of Table VII shows clearly the relatively low yield of seed from *Medicago falcata*. Allowing amply for the variation in its different forms, there is none that approaches the ordinary forms of *Medicago sativa* in seed production. In view of the extreme uncertainty of the seed crop in the case of common alfalfa, there is reason to assume that the utilization of *Medicago falcata* as a cultivated crop will be seriously handicapped by the precarious nature of its seed production.

In addition to scanty seed setting and the material loss from shattering, an appreciable percentage of the seed is "hard" and of doubtful value for sowing. As previously indicated in this paper, 50 per cent of hard seed is commonly found in the various strains of *Medicago falcata*. While the germination of a portion of this seed can be hastened by treatment, no thoroughly practicable method has yet been developed either for scratching the seed coat or rendering it more permeable to water by the use of chemicals. There is also an appreciable percentage of shriveled and nonviable seed, so that the proportion of readily germinable seed rarely exceeds 40 per cent. Preliminary tests indicate that the viability increases with age to a limited degree, aging apparently reducing the percentage of hard seed.

The comparatively small size of the seed offsets to some extent for agronomic purposes the effect of the high percentage of hard seed. There are approximately 325,000 to 490,000 seeds of *Medicago fal-*

cata per pound and only 200,000 to 250,000 seeds of *Medicago sativa* per pound. However, this difference in the size of the seed does not apparently affect the quantity necessary to produce a stand of plants in the field to the extent that theoretically might be expected.

YIELDS OF HAY.

A correct estimate of the yield of hay of *Medicago falcata* compared with that of *Medicago sativa* is difficult to make. The actual production is more nearly the same for the two species than are the yields obtained by ordinary methods of harvesting, owing to the failure of the mowing machine to cut all the procumbent or decumbent stems of the latter. Yields of hay have been obtained from a large number of individual plants cut with a hand sickle, but only a few data are available on yields from field plats harvested by machinery. The yields presented in Table VIII were obtained from tenth-acre broadcast plats at Brookings.

TABLE VIII.—*Yields of alfalfa obtained from tenth-acre broadcast plats, Brookings, S. Dak., 1910 to 1913, inclusive.*

Species.[1]	Calculated yield per acre (in pounds) based on actual yields from tenth-acre plats.														Average yield, all years.
	1910			1911			1912				1913				
	Cuttings.		Total.	Cuttings.		Total.	Cuttings.			Total.	Cuttings.			Total.	
	1	2		1	2		1	2	3		1	2	3		
Medicago sativa:															
Grimm	1,560	850	2,410	1,070	(2)	1,070	4,280	2,140	2,600	9,020	1,120	1,860	380	3,360	3,965
Do	1,500	520	2,020	860	(2)	860	4,120	2,780	2,210	9,910	1,450	1,660	280	3,390	3,845
Common	1,050	560	1,610	1,010	(2)	1,010	4,080	2,960	1,780	8,820	1,400	1,770	610	3,780	3,805
Turkestan	1,310	730	2,040	900	(2)	900	4,050	2,420	1,410	7,880	2,800	1,250	530	4,580	3,850
Medicago falcata:															
S. P. I. 20717 [3]	1,650	(2)	1,650	270	(2)	270	2,681	(2)	(2)	2,681	1,710	(2)	(2)	1,710	1,577
S. P. I. 24452 [3]	2,780	(2)	2,780	880	(2)	880	4,819	(2)	(2)	4,819	2,720	(2)	(2)	2,720	2,799

[1] All plats sown in 1909 under similar conditions. [2] No second or third crop secured.
[3] Yield in 1910 considerably increased by weeds.

It is clearly shown in Table VIII that the average yield of *Medicago falcata* is appreciably lower than the yields of the varieties of *Medicago sativa.* Only during the unfavorable years of 1910 and 1911 did the former equal or approach the latter in total hay production, and this was due largely to the growth of weeds that developed in the plats. In 1910 a very light second cutting of Grimm, common, and Turkestan alfalfas was obtained, but in 1911 only one cutting was secured.

In years that are favorable for the production of only one crop, the best hay forms of *Medicago falcata* may produce as heavy yields

as the varieties of *Medicago sativa*, and in some cases even greater yields. But where the supply of moisture is normally insufficient to produce more than one cutting a season, there is real doubt as to whether the culture of alfalfa is warranted except on a limited scale. It will be noted from Table VIII that in none of the years was more than one cutting of *Medicago falcata* produced, while in 1912 and 1913, years with favorable growing seasons, the three cuttings of *Medicago sativa* gave a total yield far in excess of that obtained even from the best number of *Medicago falcata*. In these years the *Medicago falcata* plats produced some growth after cutting, but not sufficient to be harvested by field machinery. The data in the table are supported by the results obtained by the North Dakota substation at Dickinson, N. Dak. (*64*), and by tests at Lacombe, Alberta, and Indian Head, Saskatchewan (*41*).

Estimates of yield per acre based on yields of hay from widely spaced individual plants harvested by a hand sickle are more favorable to *Medicago falcata* than are the data obtained from fields harvested by machinery. *Medicago falcata* in hills 3 feet or more apart has a tendency to produce larger plants than *Medicago sativa* under such conditions. While its recovery after cutting commonly is slight, it is frequently sufficient to permit harvesting by means of a sickle, which perceptibly increases the total yield of the season.

FEEDING VALUE.

Data procured from the various regions where *Medicago falcata* grows naturally in considerable abundance indicate that it is regarded as of high feeding value. The reports of Nilsson from Sweden; Prof. Williams,[1] of Moscow; Mr. M. S. Bogden, a Russian agronomist, Krassny Koot, Samara Government, Russia; David (*18*) from Mongolia; Galwan[1] from India; and Hansen and Meyer from numerous parts of Asia are on this point at least very favorable, if not enthusiastic.

There appear to be no available records of definite feeding tests in which *Medicago falcata* has been carefully compared with common alfalfa or other standard forage crops. If chemical analyses are accepted as an indication of the feeding value, it is reasonable to assume that this species is at least as nutritious as *Medicago sativa*. Analyses were made of samples of the former grown at Highmore and are given here mainly for comparison with the average of numerous analyses of the latter. (Table IX.)

[1] In a letter on file in the United States Department of Agriculture.

TABLE IX.—*Chemical analyses of Medicago falcata and Medicago sativa.*[1]

Species and S. P. I. No.	Group.	Chemical composition on water-free basis (per cent).				
		Ash.	Ether extract.	Protein.	Crude fiber.	Nitrogen-free extract.
Medicago falcata:						
20717	1	8.90	2.97	21.61	21.51	44.99
20725	1	9.75	2.14	19.62	29.19	39.27
20718	2	7.80	1.63	17.60	33.77	39.17
24452	2	8.13	1.81	16.02	36.98	37.03
20721	3	8.64	1.51	17.65	33.14	39.04
20722	3	10.10	1.54	18.26	30.38	39.70
28070	3	9.35	1.70	19.94	33.81	35.17
28071	3	7.84	2.30	17.21	31.96	40.67
Medicago sativa:						
Average of 21 samples[2]	.....	8.07	2.40	15.61	27.40	46.61

[1] Analyses made in the Miscellaneous Laboratory of the Bureau of Chemistry, Department of Agriculture.
[2] From Farmers' Bulletin 339, p. 28.

The analyses indicate a remarkable uniformity in the chemical composition of the various forms of *Medicago falcata* and a somewhat higher protein content than is found in the average of 21 samples of *Medicago sativa.* The relatively large proportion, by weight, of leaves to stem and the degree to which the leaves are retained on the cured plant doubtless have a bearing on this point.

The fresh leaves of practically all the forms of *Medicago falcata* are rather bitter, and this characteristic may affect to some extent their palatability, and incidentally their feeding value. Observations, however, indicate that animals eat the hay with avidity, and Meyer is of the opinion that the hay is even more palatable than that made from common alfalfa. The percentage of crude fiber in the suberect forms of the species is appreciably higher than in varieties of *Medicago sativa* and doubtless reduces their nutritive value to some extent.

Summing up the evidence briefly, it is reasonable to conclude that *Medicago falcata* is a highly nutritious forage plant and approximately equal to common alfalfa in feeding value.

CULTURAL INVESTIGATIONS.

Strictly speaking, the cultural investigations that have been conducted with *Medicago falcata* have not been extensive, owing partly to an insufficient supply of seed for large plantings and partly to the fact that other lines of investigation have been, and still are, considered of much more importance. Broadcast seeding in rows sufficiently spaced for cultivation and seeding and transplanting in widely spaced hills have been tested and the behavior of the various forms of the species observed under these conditions. In each case comparisons with common alfalfa were made as fully as possible.

BROADCAST SEEDINGS.

A serious difficulty was encountered in obtaining a satisfactory stand in tests where broadcast seeding was employed, owing primarily to the high percentage of hard seed and the slow early growth of the seedlings. Reasonably good stands were obtained, however, at Brookings in May, 1909, as the result of sowing on well-prepared land at the rate of 10 pounds per acre without a nurse crop. One of the plats had a thin stand for the first two years, but as the plants became older the low crowns spread sufficiently to produce a thick stand. (Fig. 20.) Such a condition rarely, if ever, obtains in the case of *Medicago sativa*. A stand of this species, thin at the outset, usually becomes thinner as time elapses. While the individual plants

FIG. 20.—A plat of *Medicago falcata*, Brookings, S. Dak., sown broadcast in the spring at the rate of 10 pounds to the acre.

become larger with age, the mortality in common alfalfa is sufficient to seriously deplete the stand.

In broadcast seedings the procumbent forms of *Medicago falcata* are inclined to be more nearly erect than in hills or row plantings, but even where good broadcast stands are obtained, the procumbent tendency is still sufficient to occasion considerable loss in harvesting. (Fig. 21.) In plats where *Bromus inermis* had volunteered, the loss in harvesting was appreciably diminished and a material increase in total yield was obtained. (Fig. 22.)

So far as may be determined from preliminary investigations, it would appear that although more difficulty is experienced in ob-

taining a satisfactory stand from broadcast seeding, the cultural requirements of *Medicago falcata* are essentially the same as those for *Medicago sativa.*

CULTIVATED ROWS.

There is nothing unusual in the behavior of *Medicago falcata* in cultivated rows. The yields of both hay and seed bear approximately the same relation to the yields of *Medicago sativa* under such conditions as they do in broadcast sowings. The poor germination of the seed and the slowness of growth of the seedlings occasion difficulty in the cultivation of the rows while the plants are young. This can be obviated to some extent by mixing with the seed a small

FIG. 21.—A broadcast plat of *Medicago falcata* after cutting with the mowing machine. Note the failure of the mower to cut many of the decumbent stems.

quantity of some quickly germinating seed that produces large seedlings which disappear before endangering the alfalfa plants. In experimental plantings, refuse radish seed has answered the purpose very well, but such seed is not available for planting on a field scale. A 42-inch row has given very satisfactory results in tests. On account of the spreading habit of most of the forms, rows appreciably closer than this would be somewhat difficult to cultivate after the first two or three years.

HILLS.

In some respects *Medicago falcata* is better suited to cultivation in widely spaced hills than *Medicago sativa.* The larger development of the crown of the former is an important factor in this connection.

At Brookings, plants of S. P. I. Nos. 20717 and 20725 in hills 24 by 36 inches spread to such an extent in four years that it became impossible to cultivate between the rows. In the case of these introductions the diameters of the crowns were fully twice those of the broadest crowns of the ordinary alfalfas. While these numbers represent the most spreading forms of the species, even the most erect forms produced a very large crown under such conditions. (Fig. 23.) It appears quite probable that when grown in hills the best hay forms of *Medicago falcata* will produce a better yield than *Medicago sativa* where conditions are favorable for only one cutting of the latter. However, under conditions such as ordinarily obtain at Highmore,

FIG. 22.—A broadcast plat of *Medicago falcata* in which awnless brome-grass (*Bromus inermis*) has volunteered. The brome-grass has a tendency to cause the *Medicago falcata* to grow more erectly.

the data indicate that *Medicago sativa*, even in cultivated rows or broadcast, will produce a heavier yield than *Medicago falcata* grown in hills 44 by 44 inches. At Brookings, S. P. I. Nos. 20717 and 24452 produced a heavier yield when the plants were grown in hills 24 by 36 inches than when grown in broadcast plats. On the other hand, common alfalfa produced a heavier yield in broadcast stands than in cultivated rows or hills.

TRANSPLANTING.

The transplanting of alfalfa has been suggested as a partial solution of alfalfa problems in sections having severe conditions of cold and drought. There are serious economic difficulties in the general adoption by farmers of this method of culture. Since economic con-

ditions are constantly changing and are nowhere precisely the same, it seems well to give consideration to transplanting or to any other cultural method that offers even remote possibilities. The cost incident to transplanting practically restricts the method to planting in hills. As previously pointed out, *Medicago falcata* lends itself well to this type of planting on account of its ability to spread and produce a broad crown. In addition, it apparently bears resetting better than *Medicago sativa*, which is a very important consideration. Should transplanting ever become popular, it will offer an opportunity for selected strains of *Medicago falcata* to compete with the better varieties of *Medicago sativa*.

FIG. 23.—*Medicago falcata* planted in hills 42 by 42 inches. When planted in this way the crowns make a very large development.

SEEDING ON THE RANGE.

The possibility of utilizing *Medicago falcata* in native pastures and on the range has appealed to many of the investigators who are familiar with the habits of this species in its native habitat. Both Hansen and Meyer, who have studied it in Russia and Siberia, are convinced that it can be made a valuable addition to our list of native grazing plants, especially in the northern portion of our Great Plains area. Since 1909 various tests have been conducted with it on unbroken sod. In a majority of cases the results have been of a somewhat negative character, although in comparatively few were the sowings a total failure. In the spring of 1912 rod-square plats in the native pastures of the Highmore substation were sown with the most promising forms of the species, with Grimm alfalfa in check plats. The seed was scattered upon the surface of the ground without any preparation of the soil. In 1913 a few small

plants of *Medicago falcata* were in evidence, but their ability to maintain themselves at that time seemed very doubtful. However, in 1914 some of the plants had reached a considerable size and promised to become well established in the prairie sod. Apparently, only a very few plants of the Grimm alfalfa developed. Similar experiments are being conducted at many points throughout the Great Plains region. While the results so far are not particularly encouraging, the method is worthy of trial. Plants of *Medicago falcata* are normally found so sparsely scattered in other native vegetation in those parts of Europe and Asia where the species grows that they do not furnish any great amount of grazing per unit area. However, in a new environment, such as this country offers, it is possible that the species may become much more aggressive than it is in its native habitat.

POSSIBILITIES IN SELECTION AND HYBRIDIZATION.

While there are important agronomic data still needed on *Medicago falcata* as it is introduced from Europe and Asia, it is reasonably certain that the greatest possibilities of the species lie in breeding for the development of hardy and drought-resisting strains. Selection alone offers only limited possibilities, but hybridization and selection together offer abundant opportunities for originating new and improved varieties.

SELECTION.

As they were introduced, the lots of seed of *Medicago falcata* contained a mixture of forms, and while certain of them showed considerable uniformity the majority represented such a complex that it was scarcely possible to determine the predominating type. There is already conclusive proof of the value of selection in the separation and development of superior strains of this species. Forms exist that approach *Medicago sativa* in erectness and general agronomic characteristics, and by the propagation of such forms it is possible to establish a fairly uniform strain superior to the mixed lots originally introduced.

There are several areas in this country where dry-land farming is practiced that are unfavorable for the production of more than one cutting of alfalfa a season. If the crop can be grown profitably in these sections, even if only one cutting is produced, there may be use for select strains of *Medicago falcata.* However, under the above conditions pure strains of *Medicago falcata* will meet with keen competition from hybrids of *Medicago sativa* and *Medicago falcata*, since certain of the hybrids probably are nearly or quite as resistant to cold and drought as are the pure strains of *Medicago falcata.* Furthermore, they possess the additional advantage of

yielding more abundantly. Unless a pure strain of *Medicago falcata* that will produce two or more cuttings in a season can be developed by selection, this method alone is limited in the scope of its usefulness.

When the need arrives for special strains of alfalfa for pasturage it doubtless will be met to some extent by selection from the low-growing and spreading forms of the species. Hybrid strains might have some difficulty in competing successfully with such selections, even though they do not recover quickly after cutting.

HYBRIDIZATION.

While pure strains of *Medicago falcata* for hay and pasture may find a permanent place among our cultivated crops, it is not in this rôle that the species promises to become important. Its greatest value lies in its ability to form fertile hybrids with *Medicago sativa*. This conclusion has been quite generally reached by those who have investigated the species carefully and who appreciate the important part that it has taken in the development of our commercial strains of alfalfa. An examination of early botanical and agricultural literature indicates that it was common in Europe many centuries ago, and probably it has hybridized with *Medicago sativa* since an indefinitely remote date. The effect of this on our commercial strains of alfalfa is difficult to estimate. The origin of our more or less distinct varieties of commercial alfalfa has not as yet been well determined. The readily recognizable hybrids have been roughly assigned to what is known as the variegated group and it has been assumed that those which do not show variegation in color of flowers are pure strains. Careful investigations may reveal at least a trace of *Medicago falcata* in the parentage of many distinct commercial varieties. Its part in the development of the well-known Grimm alfalfa has been fully discussed and generally recognized. Instead of indicating the possibility of developing better strains by hybridization, this recognition has had a tendency to create the impression that the chances of producing anything better than the Grimm variety through hybridization are very remote. There is, however, good ground for taking the opposite view.

The stock from which Grimm alfalfa originated came from Baden, Germany, and in all probability had been produced there for many seed generations. The hybridization which took place in the development of this stock was doubtless a more or less continuous process in which the local forms of *Medicago falcata* were the only forms concerned. There are numerous forms not found in that portion of Europe, and the possibility of obtaining hybrids between certain of these and good forms of *Medicago sativa* seems to offer a particularly promising field.

With the Grimm variety as an example of what may be accomplished through the aid of the southern forms of *Medicago falcata*, even better results may be expected from the crossing of good northern forms with *Medicago sativa*. Some very promising hybrids have already been made between the Peruvian and Arabian alfalfas and a fairly erect type of *Medicago falcata* similar to the form illustrated in figure 17. These hybrids combine valuable characters, including to a rather remarkable degree the quick recovery and growth of the Peruvian and Arabian varieties and the low crown and abundant tillering of *Medicago falcata*. Furthermore, they have proved to be reasonably hardy at Highmore. The advantages of such hybrids can readily be appreciated.

The proliferating root character, as found in certain forms of *Medicago falcata*, has only recently been observed in this country. By the use of this character, high-yielding strains may be originated that will be especially resistant to severe climatic conditions and actually aggressive on soils of fairly loose texture.

The above are only a few of the possibilities that are offered to the plant breeder by this diverse species, and those who fail to see beyond its agronomic defects as it exists in its natural state are missing an opportunity in the field of plant breeding.

ARTIFICIAL AND NATURAL HYBRIDIZATION.

There are two ways of utilizing *Medicago falcata* in the development of hybrid strains of alfalfa; namely, in the making of natural and of artificial hybrids. The latter is the more definite and promising method, but the former unquestionably offers possibilities. In the making of artificial hybrids both parents may be carefully chosen and rigid selection made in the progeny. While the expense incident to this method is considerable, satisfactory results can be secured from it in a much shorter time than from the latter method. Pollination by artificial means is easily accomplished, either by what is termed the depollination method or by tripping the flower of the plant selected for the female parent on a knife blade or similar instrument upon which pollen from another plant has been collected. On account of its comparative simplicity the latter method is generally preferred. It appears to be true that the pollen of *Medicago falcata* is prepotent over that of *Medicago sativa* on the stigmas of the latter, and vice versa. At any rate, there is very little difficulty in effecting reciprocal crosses between the two species. Methods of pollination have been fully discussed in bulletins of the Department of Agriculture (*46*) and other institutions.

The fact that the hybridization which has produced the variegated commercial strains of alfalfa has been the result of natural agencies leads to the belief that with careful work still better results may

be obtained. In sections where climatic conditions are reasonably favorable for seed production, hybrid strains could soon be developed by establishing a few plants of *Medicago falcata* in a field of *Medicago sativa* or in the fence rows and margins of the fields. A heterogeneous collection of hybrids would develop from this method, but with the assistance of natural eliminating agencies appreciable good would result, especially in sections where drought and winterkilling are important factors.

DIFFICULTIES IN ESTABLISHING NEW STRAINS.

The difficulties in establishing a new variety or strain of alfalfa must not be underestimated. There are three important factors that seriously interfere with the maintenance of pure strains of this crop; namely, the open fertilization of the flowers, the lack of distinct varietal differences in seed and other botanical characters, and the mixing of the seed either as the result of careless or unscrupulous handling. With regard to the first-mentioned handicap it has been suggested that only one variety of alfalfa be grown in a community, and in this way the chances for the contamination of the strain through the medium of cross-fertilization with other strains would be reduced to a minimum. Under present conditions, this plan is not feasible, since it would be difficult, if not quite impossible, to get farmers to organize properly for such a purpose.

A wide difference of opinion exists as to the effect on the characters of a given strain of the cross-fertilization that takes place in alfalfa under average field conditions. Brand (*13*) offers it as an explanation for the failure of a certain lot of Grimm alfalfa to survive the winter to the same degree as other lots of this variety tested with it, even though it had been directly exposed to cross-pollination for only one seed generation. Oliver[1] is likewise of the opinion that the cross-pollination that normally takes place in alfalfa is a serious detriment to the establishment of superior strains, and he cites the case of Peruvian alfalfa in the Southwest in this connection. Field observations, however, do not seem to justify the belief that the Peruvian variety will soon lose its identity through cross-fertilization in the Southwest. In fact, there is no appreciable evidence that deterioration has occurred from this cause. That strains of alfalfa will lose their distinct characteristics as the result of continued crossing with other strains can scarcely be questioned, some strains perhaps being more susceptible than others. It also appears to be true that it is a mistake to attempt to breed alfalfa along narrow lines. Taking everything into consideration, it is safe to conclude that the first of the three factors mentioned is the least important.

[1] In an unpublished paper.

Lack of distinct differences in the appearance of varieties, especially in seed characters, handicaps the promotion of new alfalfas. Striking differences excite interest on the part of farmers, while lack of them affords opportunity for fraudulent practices in connection with the sale of seed. Unless a variety is markedly different from one that is commonly grown, either in general appearance or in adaptation to certain conditions, farmers are not apt to take more than a passing interest in it. The real differences between varieties are not always visible. Hardiness and drought resistance, while highly important characteristics, can not be readily determined. Fortunately, the so-called variegated group, containing readily recognizable hybrid alfalfas and including our hardiest and most drought-resistant strains, is sufficiently distinct from the common, Peruvian, and Arabian groups to be recognized by those who are familiar with these groups. This lessens the confusion and has a tendency to discourage to some extent the practice of seed adulteration and misbranding.

There are at present several commercial strains belonging to the variegated group, which complicates to some extent the establishment of new strains of this broad group. However, the newly created varieties resulting from a cross between *Medicago sativa* and *Medicago falcata* have a preponderance of variegated flowers unless selected to a narrow type, and this assists in distinguishing such strains from the Grimm and similar older strains.

Careless planting, harvesting, and cleaning, and, most important of all, the willful substitution and adulteration of seed, soon undo the work of careful breeding. These are the most serious handicaps to the permanency of a new and superior variety. A considerable degree of carelessness is certain to result, and the high price at which seed of new varieties commonly is held offers a strong inducement for fraud. Regardless of the care that has been taken and the warnings that have been issued, there are thousands of pounds of seed of other varieties sold annually under the name of Grimm. Properly drafted and administered seed-control laws assist in keeping down such practices, but in many cases positive proof of fraud can not be produced until after the harm has been done.

Since it would seem that the life of a distinct and superior variety of alfalfa under our present conditions is not long, it is more advantageous to develop continuously new varieties than to endeavor to perpetuate pure stocks of the old ones. This leaves a large field for the various forms of *Medicago falcata*. Even if the hybrid strains that are now used can not be improved upon, there will be need for new ones to take their place when they have lost their identity through mixing with other strains.

PRESENT AGRONOMIC STATUS.

The investigations of the Department of Agriculture on a large number of forms of *Medicago falcata* during the past eight years have not determined definitely their agricultural status, but they indicate quite clearly the rôles which they may be expected to fill while our economic conditions remain substantially as they are at present. In an endeavor to make clear the agricultural status of these new alfalfas as it appears at this time, a summary is here presented, in which are set forth the important difficulties in the way of their utilization, together with a brief discussion of their advantages and possibilities as cultivated forage crops.

Slow recovery after cutting, resulting in the production of only one crop of hay in a normal season, is a characteristic of all the forms of the species under observation, with the possible exception of certain introductions from India. This is perhaps the chief handicap to their becoming generally cultivated, as it limits the yield to a point of doubtful profit. The decumbent habit of most forms is not characteristic of all, there being some that are sufficiently erect to be harvested successfully by field machinery. Lack of erectness, therefore, can not be considered as an objection to the species as a whole.

A difficulty, however, of no small importance is found in the seed habits of this species. The quantity of seed that can be successfully harvested under the most favorable conditions is small compared with that from common alfalfa, and the percentage of hard seed is so high as to require a considerable quantity at the time of seeding to secure a satisfactory stand. The high percentage of hard seed, together with the slow growth of the seedlings, makes it difficult to obtain a good stand and maintain it against weeds, especially under conditions of broadcast seeding. The minor objections to *Medicago falcata* as a cultivated crop have already been pointed out and need not be dwelt upon further.

The systematic introduction of the species was prompted by a desire to find strains of alfalfa sufficiently hardy and drought resistant to grow successfully in the colder and drier portions of the country. Apparently, many of these forms are able to withstand severe conditions of cold and drought, to the extent at least of maintaining an existence, and in much of the area where dry-land farming is now practiced the best strains will produce one cutting in a season from planting in hills and rows, if not from broadcast seedings.

There are two very important questions that present themselves in this connection. (1) Will these new alfalfas produce one good cutting annually in sections now considered too dry for successful

agriculture? No encouraging answer can be given to this question at the present time. (2) Will the yield from the one cutting that they may be expected to produce be sufficiently large to make their extensive culture profitable? The answer in this case is not very optimistic. It is quite probable, however, that conditions exist under which a limited area of alfalfa would be valuable, even where only one cutting, of a ton or somewhat less per acre, is all that could be expected in a season. If this be true, certain of the best hay-producing strains of *Medicago falcata* may have an advantage under such conditions over the best strains of *Medicago sativa* that are now available, not only because of their hardiness and drought resistance, but also because of their apparent ability to produce a somewhat heavier yield from the one cutting. But whether they possess a material advantage over the best hybrids of the two species is by no means certain.

Economic conditions are slowly changing. The feasibility of establishing alfalfa fields in dry areas where agriculture is precarious, either by seeding or by the transplanting of seedling plants, is now being considered. The varieties of *Medicago falcata* lend themselves well to this type of culture. In widely spaced hills the individual plants make a very large development, and the young plants bear transplanting better than plants of *Medicago sativa*. The time for the extensive culture of alfalfa in hills for forage is probably very far distant, as is the extensive growing of the crop under any system of culture in sections where only one cutting can be procured each season, so that the alfalfa problem is by no means solved by the securing of so-called hardy and drought-resistant strains. To become generally useful these alfalfas must produce a sufficient yield to be profitable and to compete with the cereals and other crops that can be utilized for forage.

To what extent *Medicago falcata* will be found of value in connection with the improvement of our native pastures and ranges can not definitely be stated at this time. The field is a very broad one, and critical data are still wanting. The results of investigations to date, however, do not warrant any considerable degree of optimism. Experimental plantings on native sod have been established, but the plants so far have failed to exhibit the aggressiveness that is necessary to make them valuable. Under cultivation in the more favorable sections the species offers somewhat greater promise. Its forms possess certain characteristics that fit them for pasturage purposes. The spreading habit and development of rhizomes and proliferating roots enable them to endure grazing and trampling to a considerable degree. For pasture, as well as for the production of hay, however, their slow recovery makes it very doubtful whether they will be able to compete successfully with the better hybrid strains.

It is in the field of plant breeding that *Medicago falcata* offers its greatest usefulness, and in this field its possibilities have been only partially developed. Our most hardy and drought-resistant alfalfas have been developed as a result of natural hybridization with *Medicago sativa* and subsequent natural selection. By the artificial crossing of *Medicago sativa* with forms of *Medicago falcata* that possess striking and valuable characteristics, such as are offered by the abundant material now available, it has already been demonstrated quite definitely that strains of alfalfa appreciably superior to even the best now available can be originated. Furthermore, it is now generally recognized that the only practicable way of maintaining superior strains is by developing new ones continuously. The whole field of investigation so far as *Medicago falcata* is concerned is still open to those who are amply equipped, both financially and by training, to do careful investigational work. It is believed that the burden of the development of this species to the point where it can be successfully utilized should fall on the United States Department of Agriculture, the State agricultural experiment stations, and similar institutions, and not on the farmer. Furthermore, the farmer is advised to go to no great expense in procuring seed of the forms of the species now available, since the returns which he might reasonably expect will scarcely be commensurate with the expense involved.

The breeding work is being done as rapidly as possible, and just as soon as it has reached the point where promising strains, either pure or of hybrid origin, have been perfected, they will be made available to the public.

SUMMARY.

The first importation of *Medicago falcata* into the United States of which there is a record was made in 1897. The first systematic introductions for the purpose of utilizing the species as a cultivated forage crop were made in 1906 by Prof. N. E. Hansen under the auspices of the United States Department of Agriculture. Since that date many lots of seed representing various forms of the species have been introduced by Prof. Hansen, Mr. Frank N. Meyer, and various others. Approximately fifty lots have been introduced, mostly from Russia and Siberia.

At the present time *Medicago falcata* is found growing without cultivation in most parts of Europe and the western two-thirds of Asia. Over a large portion of this area it probably is indigenous. It is found throughout a wide range of soil and climatic conditions and at depressions and elevations ranging from below sea level to 13,000 feet above. It is much wider in its adaptations than *Medicago sativa.*

The species was recognized by botanists early in the history of modern botany, if not long before. Recent botanists differ somewhat with regard to its taxonomic relationship to *Medicago sativa*. Some give it the rank of a true species, while others regard it as a variety or subspecies of the latter. The natural relationship of the two, however, is quite clearly shown by the readiness with which they hybridize and the fertility of their hybrids.

It is an extremely variable species, many forms of which are difficult to classify satisfactorily on account of their varying combinations of characters and the difficulty of determining whether they are of pure or hybrid origin. A classification or grouping has been attempted in this paper largely upon the basis of habit of growth. Four groups have been established, ranging in habit from prostrate to almost erect. The first two are referred to as pasture groups, as they are not sufficiently erect to be harvested satisfactorily for hay by machinery. The last two are sufficiently erect to be harvested for hay and are referred to as hay groups.

Botanists have named and described several varieties of the species, many of which have proved to be hybrids of *Medicago falcata* and *Medicago sativa*.

Medicago falcata has never been extensively cultivated in Europe or Asia, although it has been utilized as a wild forage plant since a very early date. Many attempts have been made to grow it under cultivation in Europe, but so far as can be found it is now being cultivated only in India and, possibly, to a very limited extent in southeastern Russia and Chinese Turkestan.

Numerous common names have been proposed for the species, but so far none is satisfactory. The name by which it is most generally known in this country is yellow-flowered alfalfa. It is probable that this name will finally be adopted.

The erect forms of *Medicago falcata* resemble very closely those of *Medicago sativa* in their mass effect, but on an average they produce a heavier yield in comparison with their bulk, partly because of the more numerous stems and partly because of the texture of their herbage. Under similar conditions of soil and stand of plants the best strains of *Medicago falcata* frequently outyield the best varieties of *Medicago sativa* for the first cutting of the season.

A very serious drawback to the general utilization of *Medicago falcata* as a cultivated forage crop is its inability to recover quickly after cutting. Under conditions such as exist in the West and Northwest, where it appears to offer its greatest possibilities, it can be depended upon to make only one crop in a season. It produces seed sparingly and does not hold it as retentively as does *Medicago sativa*. This is also a serious handicap to its use as a cultivated crop.

The natural range of distribution of the species, its specific adaptations, and its behavior under field conditions in this country warrant the conclusion that it is relatively hardy and drought resistant.

Chemical analyses and general feeding tests indicate that it is approximately as valuable from a feeding standpoint as common alfalfa.

The cultural requirements of *Medicago falcata* appear to be much the same as those of *Medicago sativa*. On account of the hard seed which the former produces and the slow growth of the young plants it is difficult to secure a satisfactory stand from seeding, either broadcast or in rows. When grown in broadcast stands the procumbent forms are inclined to be more nearly erect than when grown in rows or hills. The plants of this species bear transplanting better than do those of *Medicago sativa*.

Data from broadcast plats of *Medicago falcata* and *Medicago sativa* indicate that in seasons when only one cutting of the latter can be procured the former produces the heavier yield, but in favorable seasons, when two or more cuttings can be procured, the latter excels appreciably in yield.

Sowings of *Medicago falcata* have been made on unbroken native sod land and a fair stand of plants secured. The plants appear to lack sufficient aggressiveness to make them really valuable under such conditions.

The greatest possibilities offered by the species appear to be in the field of selection and hybridization. In a few cases it is probable that the development of promising pure strains by selection will prove to be advantageous. As the result of hybridizing with *Medicago sativa* and subsequent selection it is believed that superior varieties of alfalfa can be developed and that the greatest value of the species is for this purpose.

Much time and effort will be required before *Medicago falcata* will be ready for general cultivation.

LITERATURE CITED.

(1) Alefeld, F. G. C.
1866. Landwirtschaftliche Flora . . . p. 75–76. Berlin.

(2) Ascherson, P. F. A., and Graebner, Paul.
1898–99. Flora des Nordostdeutschen Flachlandes (ausser Ostpreussen). p. 432. Berlin.

(3) Babey, C. M. P.
1845. Flore Jurassienne . . . t. 1, p. 363. Paris.

(4) Baker, J. G.
1879. Leguminosæ. *In* Hooker, J. D. Flora of British India. v. 2, p. 90. London.

(5) Balbis, G. B.
1801. Elenco delle Piante Crescenti ne' Contorni di Torino. p. 93. Torino.

(6) Bauhin, Johann.
1651. Historia Plantarum Universalis . . . t. 2, p. 383. Ebroduni.

Bauhin, Kaspar.
(7) [1596.] Phytopinax . . . p. 661. Basiliæ.

(8) 1623. Pinax . . . p. 330. Basiliæ Helvet.

(9) Besser, W. S. J. G. von
1809. Primitiae Florae Galiciae Austriacae Utriusque. pars. 2, p. 127. Viennae.

(10) Bock, Hieronymus.
1552. De Stirpium . . . Commentariorum libri tres . . . p. 591. Argentorati.

(11) Boenninghausen, C. M. F. von.
1824. Prodromus Florae Monasteriensis Westphalorum . . . p. 225. Monasterii.

Brand, C. J.
(12) 1907. Peruvian alfalfa: A new long-season variety for the Southwest. U. S. Dept. Agr., Bur. Plant Indus. Bul. 118, p. 8.

(13) 1911. Grimm alfalfa and its utilization in the Northwest. U. S. Dept. Agr., Bur. Plant Indus. Bul. 209, p. 26.

(14) Briggs, L. J., and Shantz, H. L.
1914. Relative water requirement of plants. *In* Jour. Agr. Research, v. 3, no. 1, p. 61.

(15) Chabré, Dominique.
1666. Stirpium Icones et Sciagraphia . . . p. 165. Genevae.

(16) Cusin, L. A., and Ansbergue, Edmé.
1869. Herbier de la Flore Francaise. [t. 5/6], pl. 1011. Lyon.

(17) Dalibard, T. F.
1749. Florae Parisiensis Prodromus . . . p. 229. Paris.

(18) David, A.
1870. Extrait d'une lettre de M. l'abbé A. David adressée à M. Decaisne. *In* Flore des Serres, t. 18, p. 126.

Dillenius, J. J.
(19) 1718. Catalogus Plantarum Circa Gissam Sponte Nascentium; Cum Observationibus Botanicis, Synonymiis Necessariis, Tempore & Locis, in quibus Plantae Reperiuntur . . . p. 148. Francofurti ad Moenum.

(20) 1719. Catalogus Plantarum Sponte Circa Gissam Nascentium. Cum Appendice . . . p. 130. Francofurti ad Moenum.

(21) Fries, E. M.
1842. Novitiae Florae Suecicae Continuatio . . . Mantissa III. p. 91–92. Lundae et Upsaliae.

(22) Gaudin, J. F. G. P.
1829. Flora Helvetica . . . v. 4, p. 611–612. Turici.

(23) Georgeson, C. C.
1912–15. [Alfalfa.] *In* Alaska Agr. Exp. Sta. Ann. Rpt. 1911, p. 27; 1912, p. 35–36; 1914, p. 17–18; 1914, p. 31. 1912–1915.

(24) Gesner, Konrad.
1561. Horti Germaniae . . . *In* Cordus, Valerius. In Hoc Volumine Continentur . . . Annotationes in Pedacij. Dioscoridis Anazarbei de Medica Materia Libros V . . . p. 267. [Argentorati.]

(25) Godron, D. A.
1843. Flore de Lorraine . . . t. 1, p. 169, Nancy.

(26) Hansen, N. E.
1909. The wild alfalfas and clovers of Siberia, with a perspective view of the alfalfas of the world. U. S. Dept. Agr., Bur. Plant Indus. Bul. 150, p. 10, 12, 14.

(27) Hy, F.
1895. Observations sur le Medicago media Persoon. *In* Jour. Bot. [Paris], ann. 9, no. 23, p. 431–432.

(28) Jacquin, N. J. von.
1770. Hortus Botanicus Vindobonensis . . . [v. 1], p. 39. Vindobonae.

(29) Koch, W. D. J.
1837. Synopsis Florae Germanicae et Helveticae . . . p. 160. Francofurti ad Moenum.
Ed. 2, p. 176. Francofurti ad Moenum, 1843.

(30) ——— ed.
1839. J. C. Röhlings Deutschlands Flora . . . Bd. 5, p. 318. Frankfurt am Main.

(31) Lamarck, J. B. P. A. de M. de.
1789. Encyclopédie Methodique. Botanique. t. 3, 631. Paris.

(32) Le Blanc, Thomas.
1791. Experiments on the variegated medick. *In* Ann. Agr., v. 15, p. 279.

L'Écluse, Charles de (Clusius).
(33) 1583. Rariorum aliquot Stirpium, per Pannoniam, Austriam, & Vicinas Quasdam Pronuincias Obseruatarium Historia. Qvatvor Libris Expressa. p. 758–760. Antverpiae.

(34) 1601. Rariorum Plantarum Historia . . . liber vi, p. ccxliii. Antverpiae.

(35) LEDEBOUR, K. F. VON.
1842. Flora Rossica . . . v. 1, p. 526. Stuttgartiae.

LINDEMANN, E. E.
(36) 1881. Flora Chersonensis. v. 1, p. 138. Odessae.
(37) 1867. Florula Elisabethgradensis . . . *In* Bul. Soc. Imp. Nat. Moscou, t. 40, pt. 1, p. 495.

LINNÉ, CARL VON (LINNÆUS).
(38) 1737. Hortus Cliffortianus . . . p. 377. Amstelaedami.
(39) 1745. Flora Suecica . . . p. 223, no. 620. Lugduni Batavorum.
(40) 1753. Species Plantarum . . . v. 2, p. 779. Holmiae.

(41) MACKAY, ANGUS.
1912. [Report of] experimental farm for southern Saskatchewan. Cultivation, seeding, and harvesting of alfalfa. *In* Canada Exp. Farms Rpts. [1911]/12, p. 320.

(42) MCKEE, ROLAND.
1913. Arabian alfalfa. *In* U. S. Dept. Agr., Bur. Plant Indus. Circ. 119, p. 27.

(43) MARTYN, THOMAS.
[1792.] Flora Rustica . . . v. 3, p. 86–87. London.

(44) MORISON, ROBERT.
1715. Plantarum Historiae Universalis Oxoniensis . . . t. 2, p. 157; sect. 2, pl. 15, fig. 1, pl. 16, fig. 1. Oxonii.

(45) OAKLEY, R. A., and GARVER, SAMUEL.
1913. Two types of proliferation in alfalfa. *In* U. S. Dept. Agr., Bur. Plant Indus. Circ. 115, p. 3–13, 8 fig.

OLIVER, G. W.
(46) 1910. New methods of plant breeding. U. S. Dept. Agr., Bur. Plant Indus. Bul. 167, 39 p., 2 fig., 15 pl.
(47) 1913. Some new alfalfa varieties for pastures. U. S. Dept. Agr., Bur. Plant Indus. Bul. 258, 39 p., 11 pl.

(48) PERSOON, C. H.
1807. Synopsis Plantarum . . . pars 2, p. 356. Parisiis Lutetiorum.

(49) REICHENBACH, H. G. L.
1832. Flora Germanica . . . sect. 3, p. 504. Lipsiae.

(50) RIVINUS, A. Q.
1690. Ordo Plantarum, quae sunt Flore Irregulari Monopetalo. p. 84. Lipsiae.

(51) ROUY, GEORGES, and FOUCAUD, JULIEN.
1899. Flore de France . . . t. 5, p. 10–15. Asnières (Seine), Paris.

(52) ROYEN, ADRIAN VAN.
1740. Florae Leydensis Prodromus . . . p. 381. Lugduni Batavorum.

(53) SCHÜBELER, F. C.
1888. Viridarium Norvegicum . . . Bd. 2, p. 547. Christiania.

(54) SCHULTES, J. A.
1809. Observationes Botanicae in Linnaei Species Plantarum ed editione C. L. Willdenow. p. 160. Oeniponti.

SCHUR, J. F.
(55) 1866. Enumeratio Plantarum Transsilvaniae Exhibens. p. 151. Vindobonae.

(56) 1876. Photographische Mittheilungen über Pflanzenformen aus verschiedenen Florengebieten des Oesterreichischen Kaiserstaates. *In* Verhandl. Naturf. Ver. Brünn, Bd. 15, Heft 2, p. 171–172.

(57) SERINGE, N. C.
1825. Medicago. Sect. II, Lupularia. *In* Candolle, A. P. de. Prodromus . . . pars 2, p. 172–174. Parisiis.

(58) THEODORUS, JACOBUS (TABERNÆMONTANUS).
1591. Neuw Kreuterbuch . . . t. 2, p. 204. Frankfort a. M.

(59) TOURNEFORT, J. P. DE.
1694. Elemens de Botanique . . . v. 1, p. 327–328. Paris.

(60) 1700. Institutiones Rei Herbariae . . . ed. 2, t. 1, p. 410; t. 2, pl. 231. Parisiis.

(61) TRAUTVETTER, E. R. VON.
1860. Enumeratio plantarum Songoricarum a Dr. Alex. Schrenk annis 1840–1843 collectarum. *In* Bul. Soc. Imp. Nat. Moscou, t. 33, pt. 1, p. 474.

(62) URBAN, IGNATZ.
1873. Prodromus einer Monographie der Gattung Medicago L. *In* Verhandl. Bot. Ver. Prov. Brandenburg, Jahrg. 15, p. 56–57.

(63) VAILLANT, SÉBASTIEN.
1727. Botanicon parisiense . . . p. 124. Leide.

(64) WALDRON, L. R.
[1911.] Drawbacks of Medicago falcata. *In* N. Dak. Agr. Exp. Sta., 3d Ann. Rpt. Dickinson Sub-Exp. Sta. 1910, p. 16.

(65) WALLROTH, K. F. W.
1822. Schedulae Criticae de Plantis Florae Halensis Selectis. I. Phanerogamae . . . p. 398. Halae.

(66) WESTGATE, J. M.
1910. Variegated alfalfa. U. S. Dept. Agr., Bur. Plant Indus. Bul. 169, p. 46.

(67) WIDTSOE, J. A.
[1897.] The chemical life history of lucern. Utah Agr. Exp. Sta. Bul. 48, p. 15.

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